Barwon-Darling Water Resource Plan

Surface water resource description
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1. Introduction

The NSW Government is developing water resource plans as part of implementing the Basin Plan 2012 (the Basin Plan). Water resource plans will align Basin-wide and state-based water resource management in each water resource plan area. These plans will recognise and build on the existing water planning and management framework that has been established in NSW.

The Barwon-Darling Water Resource Plan covers a single surface water resource, the Barwon-Darling Unregulated River Water Source. This report is a detailed description of the surface water resources of the Barwon-Darling Water Resource Plan Area (SW12) to provide an understanding of the region and the resources covered by the plan. The report describes the location and physical attributes and provides background information on the hydrology, environmental assets and water quality characteristics relevant to this water source.

This report provides supplementary information to other components of the Barwon-Darling Water Resource Plan including the Risk Assessment and Water Quality Management Plan.

1.1 Overview of the plan area

The Barwon-Darling Water Resource Plan Area (WRPA) comprises the main channel of the Barwon-Darling River, which is part of the Murray-Darling Basin in western NSW (Figure 1). The Barwon-Darling River begins at the junction of the Weir River and Macintyre River upstream of Mungindi and flows 1,900 km through western NSW until it enters the Murray River at Wentworth. The river and its tributaries drain an area of 699,000 km² of NSW and southern Queensland. The Plan area extends to the upper limits of the Menindee Lakes downstream of Wilcannia.

Although it is considered an unregulated river, the Barwon-Darling River upstream of Menindee has been subject to significant impacts from headwater dams and water extraction, with over one third of its average annual flow being diverted from the river or its tributaries (Thoms et al. 1996).

The Barwon-Darling River is the country of Aboriginal nations Baarkindji, Ngemba and Kamilaroi, who lived along its river banks, Barundji, Kunja and Murrawari along the northern tributaries, and Wongaibon who lived on the plains south of the river. Today there are around 14,000 people living along the Barwon-Darling upstream of Menindee and in the catchments north of the river to the Queensland border. Cobar is the largest centre in the region with a population of 4,100 people. Other major service centres are Bourke, Brewarrina, Lightning Ridge and Walgett, which support populations of between 1000 and 2000 people.

Grazing accounts for 94 per cent of the catchment’s land use. The region also supports small areas of dryland cropping in the east and irrigation development along the river at Bourke.
Figure 1: Map of the Barwon-Darling WRPA

Source: Crown Lands & Water Division
1.2 Water management units
The surface water of the Barwon-Darling WRPA is currently managed through a single water sharing plan: Water Sharing Plan for the Barwon-Darling Unregulated and Alluvial Water Sources 2012. The plan establishes a single surface water source, the Barwon-Darling Unregulated River Water Source. It also establishes a single groundwater source; the Upper Darling Alluvial Groundwater Source. The Barwon-Darling water resource plan will include water sharing rules for the surface waters (unregulated river water source) only. The water source is shown in Figure 2. Water sharing rules for the groundwater source are to be included in the Darling alluvium water resource plan.

The water sharing plan establishes “management zones” and “sections” for the unregulated river water source (Figure 2). The management zones were established to enable the development of rules governing daily extraction of water that reflect local hydrological and ecological conditions. Flow volumes and travel time, for instance, vary considerably along the entire length of the river. The sections were established to facilitate trading along the Barwon-Darling River, whilst preventing third party impacts and localised environmental impacts of water trade (DPI Water 2012). The water resource plan shall adopt the management zones and sections of the water sharing plan.

1.3 History of water management in the Barwon-Darling WRPA
The recent history of water management in the Barwon-Darling WRPA is marked by four key developments: an interim flow management plan for the north-west, the adoption of environmental flow rules proposed by the Barwon-Darling River Management Committee, the introduction of a Cap on long term water take, and the commencement of the Barwon-Darling water sharing plan.

1.3.1 Interim Unregulated Flow Management Plan for the North-West
The Interim Unregulated Flow Management Plan for the North-West of NSW (the interim plan) was released in February 1992 (DPI Water 2012). The primary objective of the plan was to better manage unregulated flows to provide water quality and fish passage outcomes for the Barwon-Darling River without significantly impacting on water users.

It established:
- target flows at key locations along the Barwon-Darling
- priorities for river health and riparian flows
- a framework for sharing unregulated flows between irrigators,
- better management of water take, and
- improved monitoring and research programs.

The interim plan includes targets for riparian flows, algal suppression, and fish migration. Although the interim plan has been in place since 1992, difficulties with flow forecasting across such a large geographical area with varying antecedent conditions has limited its application to date.

1.3.2. NSW water reforms
In February 1994 the Council of Australian Governments (COAG) endorsed a strategic framework for the efficient and sustainable reform of the Australian water industry. Following this meeting, the NSW Government released a discussion paper in mid-1994 outlining changes to the management of the state’s rivers and waterways. Early reforms included the development of water quality and river flow objectives, embargoes on new licences on regulated and unregulated rivers in the Murray-Darling Basin to meet an agreed cap on water extractions from the Basin, and a commitment to deliver water to key wetlands.
Figure 2: Location of unregulated water source of the Barwon-Darling WRPA

Source: Crown Lands & Water Division
In 1997, the Government introduced its current program of rural water reforms that aimed to achieve a better balance in water use by more explicit sharing of water between the environment and water users. The program led to the development of the current legislative framework that defines how water is shared and managed under the *Water Management Act 2000*.

### 1.3.3 Environmental flow rules and Barwon-Darling River Management Committee

The NSW Government established an independent Scientific Panel in 1995 to assess the instream health of the Barwon-Darling River. The objectives of the study were to identify the hydrologic flows that were required to reverse environmental deterioration of the river, provide a rapid assessment of low flow environmental water needs, and improve the understanding of the ecology of the Barwon-Darling River. The five panel members possessed a range of expertise including freshwater ecology, geomorphology, macroinvertebrates, fish and aquatic plants.

Through field inspections, workshops and discussions with water users and other stakeholders, the Panel came up with a suite of recommendations covering water abstraction and licensing, water trading, hydrologic modelling, unregulated flow management, land management and research. Some of the key recommendations included:

- a moratorium on new extraction from the river and a ban on upstream transfer of licences
- the development of a low flow model or refinement of the existing monthly model to simulate flows on a daily basis
- flows equal to or less than 10 per cent of the channel capacity should be preserved for the ecological benefit of the system
- access to larger events should be on a sliding scale dependent on the size of the flood event.

The NSW Government then established the Barwon-Darling River Management Committee to advise on environmental flow rules for the Barwon-Darling unregulated rivers by March 1998 based on the findings of the Scientific Panel. The Committee advised the NSW Government on environmental flow rules in April 1998, which were adopted by the Government. The rules were to apply for the water years 1998-99, 1999-2000, and 2000-01, albeit with amendments following further deliberations of the Committee.

### 1.3.4 Cap on Barwon-Darling River diversions (Cap)

The Murray Darling Basing Ministerial Council (MDBMC) established the Independent Audit Group (IAG) in the lead up to the adoption of an interim limit on diversions across the Murray Darling Basin in 1995. The IAG was established to audit the continuing increase of extraction from rivers across the Murray Darling Basin. The audit found a significant and unsustainable growth in diversions that was placing stress on environmental health and reliability of water supply (MDBMC 1995, MDBMC 1996). In view of the findings of the audit, the MDBMC introduced an interim cap on further increases in diversions in June 1995. The implementation of the interim cap was then reviewed by the IAG, which made recommendations regarding the implementation of the Final Cap. The IAG’s recommendations were adopted by the MDBMC, and the Final Cap commenced 1 July 1997.

In NSW, the “Cap” was defined as the average yearly volume of water “that would have been used with the infrastructure (pumps, dams, channels, areas developed for irrigation, management rules etc) that existed in 1993/94…taking into account the climatic conditions that were experienced during the year under consideration” (MDMC 2001, p13). Where diversions exceed the Cap by more than 20 percent (the Cap target exceedance trigger), NSW was required to conduct a special audit to determine whether a systematic growth in extraction had occurred. The audit would then be reviewed by the IAG and, if necessary, the MDBMC would require NSW to rectify the breach of Cap (MDBC 1998).
The Murray Darling Basin Authority audited use in the Barwon-Darling against the Cap for the period 1989-1990 to 2011-2012. The audit found that diversions from the Barwon-Darling River were in excess of the Cap in each of the 14 years and the size of the exceedance was in each instance above the Cap target exceedance trigger (MDBA 2012). For the purposes of Cap accounting, however, the MDBMC resolved in 2000 to combine the Barwon-Darling and Lower Darling into a single designated Cap valley. Audits were subsequently undertaken for the combined valleys which found that diversions exceeded Cap in 6 of 12 years for the period 1989-1990 to 2011-2012.

In response to the audits NSW developed Cap management rules to ensure compliance with the Cap on diversions in the Barwon-Darling River valley. These rules included a reduction of licensed entitlements to Cap volumes, introduction of restricted access rules, unlimited carryover, suspension of accumulated carryover, and quotas on and reductions of announced annual water allocations (MDBMC 1996). The Cap and Cap management rules were included either in part or in full in the Barwon-Darling water sharing plan that commenced in 2012.

The reporting of Cap management through the Water Audit Monitoring Report series finished in the 2011-2012 water year. Cap management is being replaced by a system of Sustainable Diversion Limits (SDLs) established in the Basin Plan 2012. The SDLs shall take effect in 2019. During the transition period between 2012 and 2019, the use of Basin water resources is reported in Transition Period Water Take Reports prepared by the Murray Darling Basin Authority.

1.3.5 Barwon-Darling Unregulated River water sharing plan

A central element of the NSW water reforms is the development of water sharing plans for all surface and groundwater sources across NSW. The first water sharing plan for the unregulated Barwon-Darling River commenced in 2012. The plan provides the legal basis for the sharing of water between the environment and ‘consumptive purposes’ and integrates the environmental flow rules and Cap management rules developed in previous years. Under the Water Management Act 2000, the sharing of water must protect the water source and its dependent ecosystems and must protect basic landholder rights. Sharing or taking of water under any other right (licensed authority for instance) must not prejudice these rights.

The water sharing plan covers two water sources - the Barwon-Darling unregulated river and the groundwater in the Upper Darling alluvium (Figure 2). The Barwon-Darling Unregulated River Water Source includes the Barwon River from Mungindi weir to the confluence with the Culgoa River and the Darling River from this point to upstream of Lake Wetherell. Reaches of tributaries and effluents to/of the Barwon-Darling are included in the plan where licences with Barwon-Darling Cap shares nominate works on these streams. The Upper Darling alluvium includes groundwater that is associated with the Darling River upstream of Lake Wetherell.

Water sharing rules in the plan include:

- environmental water rules – the share of water reserved for the environment
- long-term average annual extraction limits – a growth-in-use assessment and management tool
- access rules – which determine when extraction is allowed (for example above a set river flow rate)
- dealing rules – which govern the trade of water, both the transfer of share components of an access licence and assignment of water allocations between water accounts, as well as changing the location for water extraction

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1 At the time of the publication of this report, the transition take reports were still in preparation, MDBA pers. comms.
The health of the Barwon-Darling River depends on floods (very high flows), freshes (high flows) and dry spells (very low flows). The environmental flow rules are designed to protect the full range of flows that are critical to river health (Photo 1). The plan establishes five flow classes - very low flows, low flows, A class flows, B class flows, and C class flows - in order to protect the range of flows. All water licences in the unregulated river water source are subject to cease to take rules that are based on these flow classes. These cease to take rules do not apply to licences held by town water supplies, local water utilities, and licences held for the purpose of food safety and essential dairy care. The cease to take access rules are specified for each of 14 management zones or river reaches within the Barwon-Darling unregulated river water source. The rules of the water sharing plan may be reviewed during the development of the Barwon-Darling water resource plan.

Photo 1: Water sharing rules help to protect high flows for floodplain wetlands such as this one at Bourke.

Dayle Green
2 Regional setting

2.1 Climate

Rainfall

Average annual rainfall in the Barwon-Darling catchment varies from 582 mm per year in the northern part of the catchment to less than 260 mm in the southern areas (Figure 3). In the more moderate middle parts of the catchment, average annual rainfall is 350 mm per year. Rainfall is generally well distributed throughout the year, however, a spring and summer dominance occurs in the upper and middle parts of the catchment (Figure 4).

Figure 3: Average annual rainfall in the Barwon-Darling WRPA

![Average annual rainfall map](image)

Source: Bureau of Meteorology Climate Data Online

Figure 4: Average monthly rainfall for selected stations

![Average monthly rainfall graph](image)

Source: Bureau of Meteorology Climate Data Online
Climate change modelling for the Far West Region (OEH 2014a) predicts that spring rainfall across the region will decrease over the next 50 years, with the largest decreases projected to occur in the southern parts of the region. Winter rainfall is projected to decrease over the next 30 years. Autumn and summer rainfall is projected to increase across the region over this timeframe (OEH 2014a).

Evaporation
Evaporation has a strong south-west to north-east gradient across the catchment. Average Class A pan evaporation varies from 1,800 mm per year in the south, to over 2,600 mm per year in the north (Figure 5). Evaporation significantly exceeds the monthly rainfall throughout the year. The average evaporation rate at Bourke in December is 282 mm, more than eight times the average rainfall for that month (Figure 6). Evaporation in winter is around 58 mm per month, compared to monthly rainfall of 27 mm.

Figure 5: Average annual evaporation across the Barwon-Darling WRPA

![Average annual evaporation across the Barwon-Darling WRPA](source)

Source: Bureau of Meteorology Climate Data Online

Figure 6: Average monthly evaporation at Bourke 1889–2017

![Average monthly evaporation at Bourke 1889–2017](source)

Source: Bureau of Meteorology Climate Data Online
Temperature

Summer temperatures vary little across the Barwon-Darling WRPA. The mean maximum January temperature in the south (Wilcannia) and in the north (Mungindi) is 35.5°C. The mean maximum January temperature at Bourke is 36.3°C. Winters are cool to mild and mean temperatures and slightly cooler in the south. The mean maximum temperature in July at Wilcannia is 17.1°C compared to 18.9°C in the north at Mungindi.

Long-term temperature records indicate that temperatures in the Far West Region have been increasing since about 1950, with the largest increase in temperature occurring in the most recent decades (OEH 2014a). Climate change modelling for the region predicts that this warming will continue over the next 50 years, with minimum and maximum temperatures increasing by 0.7°C in the near future (2030) and 2.1°C in the far future (2070). These increases are projected to occur across the region, with a slightly greater increase in the far north-west (OEH 2014a).

The number of hot days (>35°C) is also projected to increase, with the greatest increase in hot days occurring in the northern parts with an additional 10-20 days in the near future. By 2070, the northern half of the region is projected to have 30 more hot days, with over 40 hot days for the north-western plains around Bourke. Considerable increases are projected also for the southern half of the region with 20-30 additional hot days. The region on average is projected to experience an additional 12 hot days in the near future and 35 more hot days in the far future (2070). These increases are projected to occur mainly in spring and summer, and extending into autumn in the far future (OEH 2014a).

2.2 Land use

Grazing is the main land use activity across the Barwon-Darling valley (78 per cent of total land area), followed by dryland cropping (12 per cent) (Table 1, Figure 7). Irrigated cropping, while important to the regional economy, covers only three percent of total land area and occurs mostly between Mungindi and Bourke. Cotton is the dominant irrigated crop along the river, and other enterprises include fruit, nuts and grapes (MDBA 2017, EBC 2011). Dryland cropping and horticulture predominate in the northern regions of the Barwon-Darling WRPA, whereas forestry, conservation and native vegetation predominate in the central and southern areas of the WRPA (Figure 7).

Table 1: Land use in the Barwon-Darling WRPA

<table>
<thead>
<tr>
<th>Land use</th>
<th>Area (sq. km)</th>
<th>Area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grazing</td>
<td>27740</td>
<td>78.5</td>
</tr>
<tr>
<td>Cropping</td>
<td>4211</td>
<td>11.9</td>
</tr>
<tr>
<td>Irrigated Cropping (part of Cropping above)</td>
<td>714</td>
<td>2.9</td>
</tr>
<tr>
<td>Conservation areas (incl. National Park estate and Forest Reserves)</td>
<td>1713</td>
<td>4.8</td>
</tr>
<tr>
<td>Tree and Shrub Cover</td>
<td>634</td>
<td>1.8</td>
</tr>
<tr>
<td>Wetlands</td>
<td>47</td>
<td>0.1</td>
</tr>
<tr>
<td>Horticulture</td>
<td>8.1</td>
<td>0.02</td>
</tr>
<tr>
<td>Mining and Quarrying</td>
<td>4.3</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Source: Australian Bureau of Agricultural and Resource Economics and Sciences, 2016 National scale Land use data
Figure 7: Land use map of the Barwon-Darling WRPA

Source: Australian Bureau of Agricultural and Resource Economics and Sciences, National scale land use 2010-11
2.3 Topographic and stream description

The Barwon-Darling River is characterised by low relief with 60 per cent of the catchment having elevations of less than 300 m (Thoms et al. 2004). Elevations range from 500 m around Cobar and Broken Hill in the northern extent of the WRPA to between 50 and 100 m on the floodplain between Wilcannia and Menindee. The Barwon River starts at an elevation of 200 m at the confluence of the Macintyre and Weir rivers, and flows for approximately 700 km over a low gradient to an elevation of 110 m at its confluence with the Culgoa River, north-east of Bourke. Below the Culgoa confluence, the Barwon River becomes the Darling River which flows for another 900 km to the Menindee Lakes, situated at less than 100 m elevation (MDBA 2017).

Riverine vegetation along the Barwon-Darling River is dominated by river red gums, which are found growing along the banks and around lagoons and anabranch channels. Coolibah and black box occur on higher areas of the floodplain, with coolibah woodlands occurring in the northern part of the catchment and black box in the south and west.

The Barwon-Darling River can be described in more detail with reference to the five sections of the Barwon Darling River established in the 2012 water sharing plan (Figure 2). These sections are:

- Section 1 (Mungindi to Walgett)
- Section 2 (Walgett to Brewarrina)
- Section 3 (Brewarrina to Bourke)
- Section 4a (Bourke to downstream of Louth)
- Section 4b (Downstream of Louth to Menindee)

2.3.1 Section 1 (Mungindi to Walgett)

Section 1 of the Barwon Darling River spans 344 km from Mungindi to Walgett. Major tributaries entering Section 1 include the Border Rivers (Macintyre and Weir Rivers), the Boomi River, Gwydir River and Namoi River. This section of the river has a relatively narrow floodplain with a tightly meandering channel and many in-channel benches. The channel capacity is highly variable, ranging from 4,000 ML/d near Mungindi to 50,000 ML/d upstream of Walgett. The channel width varies from 40 to 60 metres and the depth may be up to 10 metres (Thoms et al. 1996).

Eight weirs are located along this Section. Licensed extraction occurs from above Collarenebri to Walgett with more than 39,000 ML/year estimated to be used from this section (more than 20 per cent of extraction in the WRPA). The average daily flow through this section is 3,283 ML/day, the average annual 80th percentile flow is 133 ML, and the 2nd percentile flow is 14,590 ML/day (Site 422003, Barwon River at Collarenebri).

Between Mungindi and Prestbury Weir, 78 per cent of floodplain wetlands commence filling at flows of less than 4,000 ML/day. A further 22 per cent of wetlands fill between 9,000 and 17,000 ML/d (Brennan et al. 2002). Between Prestbury Weir and Collarenebri, 30 per cent of floodplain wetlands commence filling at flows of 1,000-2,000 ML/day, and 60 per cent of wetlands commence filling between 19,000-30,000 ML/day (Brennan et al. 2002). River flows at or above 18,000 ML/day will drown out Collarenebri Weir (NSW DPI 2015a) (Photo 2).

2.3.2 Section 2 (Walgett to Brewarrina)

Section 2 spans the Barwon River for 325 km between Walgett and Brewarrina. The floodplain widens downstream of Walgett as it flows unrestricted across alluvial plains with few bedrock outcrops to restrict its path (Photo 3). The channel is less sinuous, but there are many anabranches and effluent channels, which split from, and later re-join, the main channel. Major tributaries that flow into this reach are the Namoi, Macquarie-Castlereagh, Narran and Bokhara rivers.
Major weirs occur upstream at Walgett and downstream at Brewarrina. Flows of 14,000 ML/d or more are needed to drown out Walgett Weir (NSW DPI 2015a). A fishway was installed at Brewarrina Weir in 2013, providing fish passage at low flows along a substantial length of river between Walgett and Bourke (NSW DPI 2015). More than 50,000 ML/year is estimated to be taken for licensed extraction in Section 2 (around 29 per cent of extraction from the WRPA). At gauge 422027, Barwon River at Geera, the average annual 80th percentile flow is 213 ML/day and the 3rd percentile flow is 32,968 ML/day.

Eighty-six per cent of the floodplain wetlands along this reach are filled when flows are between 9,000 and 32,000 ML/day (Brennan et al. 2002). Approximately 70 per cent of snags (instream woody debris) are inundated by small flow pulses of 8,000 ML/day at Walgett (NSW DPI 2015a).

2.3.3 Section 3 (Brewarrina to Bourke)

Section 3 between Brewarrina Weir and Bourke Weir is 250 km long. Major tributaries entering this section include the Bogan River from the east and the Culgoa River from the north-west. The channel capacity increases to more than 80,000 ML/d near Bourke with a channel width of 60-80 metres and a depth of up to 20 metres (Thoms et al. 1996). It is estimated that there is more than 70,000 ML/year extracted from this section of the river (around 37 per cent of extraction in the WRPA). The average daily flow at gauge 425003 on the Darling River at Bourke is 9,464 ML/day. The average annual 80th percentile flow is 405 ML/day, and the 4th percentile flow is 31,375 ML/day.

Eighty-two per cent of floodplain wetlands begin filling at flows between 11,000 and 32,000 ML/day, while 12 per cent of wetland fill between 47,000 and 60,000 ML/day (Brennan et al. 2002). River flows at or above 10,000 ML/day drown out Bourke Weir (NSW DPI 15a). Nearly half of the woody debris in this section of the river is inundated with a flow of 6,000 ML/day at Bourke (NSW DPI 2015a). Significant river rehabilitation has been undertaken along this section since 2006 to improve fish habitat, enhance native fish abundance, and reduce the impact of exotic fish species and barriers to fish movement (NSW DPI 2013).

2.3.4 Section 4a (Bourke to downstream of Louth)

Section 4a between Bourke Weir and Louth Weir spans 308 km of the Darling River and includes four major weirs. Downstream of Bourke the Darling River is strongly influenced by geological controls which determine its course in a southwest direction. The river flows within a deeply incised channel with few channel benches and a narrow floodplain (Photo 4). The channel width is between 60 to 80 metres and channel depth up to 25 metres. The Warrego River is the major tributary entering this section of the river.
It is estimated that licensed extraction from this section is more than 20,000 ML/d with the majority of this occurring above the Warrego River confluence. The average daily flow is 8,660 ML/day at gauge 425004 on the Darling River at Louth (Photo 5). The average annual 80th percentile flow is 392 ML/day and the average annual 2nd percentile flow is 52,272 ML/day.

The majority of floodplain wetlands (77 per cent) begin filling when flows in the Barwon-Darling River are between 14,000 and 50,000 ML/day while 7 per cent of wetlands fill at higher flows between 59,000 and 82,000 ML/day (Brennan et al. 2002). Louth Weir is drowned out at flows of 9,000 ML/day or more (NSW DPI 15a). Approximately 40 per cent of snags between Bourke and Tilpa are inundated when flows downstream of Weir 19A are equal to or greater than 6,000 ML/day (NSW DPI 2015a).

2.3.5 Section 4b (Downstream of Louth to Menindee)

Section 4b extends for 747 km along the Darling River between Louth Weir and Menindee. It includes major weirs at Tilpa and Wilcannia. The Paroo River joins the Darling River in this section although it rarely contributes any flow. Downstream of Tilpa the Darling River flows through sediments of the Murray Basin and the number of in-channel benches increases compared to the upstream section around Bourke.

This section of the river supports the lowest level of extraction, estimated to be around 4,000 ML/year which is two per cent of extraction in the WRPA. The average daily flow at gauge 425008 on the Darling River at Wilcannia is 6,374 ML/day. The average annual 80th percentile flow is 242 ML/day and the 2nd percentile flow is 32,800 ML/day.

Around 23 per cent of wetlands are filled at flows between 8,000 and 26,000 ML/day, while more than half of wetlands (54 per cent) begin to fill between 29,000 and 35,000 ML/d (Brennan et al. 2002). Flows of 2,400 ML/day will drown out Tilpa Weir while flows of 7,900 ML/day will drown out Wilcannia Weir (NSW DPI 2015a). Low flows of 6,000 ML/day will inundate 28 per cent of the snags between Tilpa and Wilcannia (NSW DPI 2015a).
2.4 Streamflow characteristics

A network of 24 river gauges record stream flows on a continuous basis along the Barwon-Darling River upstream of Menindee. Table 2 shows mean daily flows recorded at a number of these gauges. Mean daily flow increases with increasing channel capacity between Mungundi and Bourke, with an average daily flow of 9,452 ML at Bourke. Mean daily flow decreases downstream of Bourke due to the reduced contribution of tributaries and higher evaporation (Thoms et al. 2004b). Of the tributaries to the Barwon Darling River, the Border Rivers catchment is the largest, contributing up to 35 per cent of long term flow recorded at Menindee (Table 3). The Namoi and Condamine-Culgoa system are the next largest contributors. Together, these three eastern catchments account for 80 per cent of Darling River’s flow. The largest flows tend to be the result of summer rainfall, and hence flood events are more likely in summer and autumn (Thoms et al. 2004b).

Table 2: Mean daily flow for Barwon-Darling gauges

<table>
<thead>
<tr>
<th>Gauge site</th>
<th>Catchment area ($\text{km}^2$)</th>
<th>Mean daily flow (ML)</th>
<th>Period of record</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barwon River at Mungundi</td>
<td>44,070</td>
<td>1,641</td>
<td>1889-2016</td>
</tr>
<tr>
<td>Barwon River at Collarenebri</td>
<td>85,500</td>
<td>3,305</td>
<td>1944-2016</td>
</tr>
<tr>
<td>Barwon River at Dangar Bridge (Walgett)</td>
<td>132,200</td>
<td>4,681</td>
<td>1886-2016</td>
</tr>
<tr>
<td>Barwon River at Brewarrina</td>
<td>297,800</td>
<td>5,609</td>
<td>1892-2016</td>
</tr>
<tr>
<td>Darling River at Bourke</td>
<td>386,000</td>
<td>9,452</td>
<td>1895-2016</td>
</tr>
<tr>
<td>Darling River at Louth</td>
<td>489,000</td>
<td>6,826</td>
<td>1904-2016</td>
</tr>
<tr>
<td>Darling River at Wilcannia</td>
<td>569,800</td>
<td>6,314</td>
<td>1913-2016</td>
</tr>
</tbody>
</table>

Source: Crown Lands & Water Division

Table 3: Contributions to long term average flow in the Darling River at Menindee

<table>
<thead>
<tr>
<th>River system</th>
<th>Flow contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condamine-Culgoa Rivers</td>
<td>20%</td>
</tr>
<tr>
<td>Border Rivers</td>
<td>35%</td>
</tr>
<tr>
<td>Namoi River</td>
<td>25%</td>
</tr>
<tr>
<td>Gwydir River</td>
<td>10%</td>
</tr>
<tr>
<td>Castlereagh-Macquarie-Bogan Rivers</td>
<td>5%</td>
</tr>
<tr>
<td>Warrego-Paroo Rivers</td>
<td>5%</td>
</tr>
</tbody>
</table>

Source: MDBC 2004

Long term annual stream flows for the upper, middle, and lower reaches of the Barwon-Darling River are presented in Figure 8, Figure 9, and Figure 10. Mean annual flow in the upper reaches of the river at Collarenebri is 1,206,602 ML however total annual flows vary considerably around this average (Figure 8). The majority of annual flows fall well below the mean, suggesting that the mean is skewed by the very large floods that have occurred during the period of record. The two largest floods occurred in 1950 and 1956. Total annual flows in 1950 reached 7,053,991 ML and 8,036,737 ML in 1956, greater than six times the average annual flow. Total annual flows are generally decreasing over the long term as indicated by the trend line.
Figure 8: Annual stream flow at Collarenebri 1945–2015

Barwon River @ Collarenebri Main Channel

Long term trend of annual flow
Mean annual flow 1,206,602 ML

Source: Crown Lands & Water Division

Figure 9: Annual stream flow at Bourke Town 1943-2014

Darling River @ Bourke Town

Long term trend of annual
Mean annual flow 3,450,027

Source: Crown Lands & Water Division

Figure 10: Annual stream flow at Wilcannia

Darling River @ Wilcannia

Long term trend of annual flow
Mean annual flow 2,304,741 ML

Source: Crown Lands & Water Division
Total annual flows in the middle reaches (Bourke) also vary considerably, despite the contributions of major tributaries to this section of the river (Figure 9). Annual flows in the middle reaches also are dominated by a small number of flood years and a large number of years total annual flows are well below mean annual flow. Tributary inflows increase the mean annual flow to 3,450,027 ML, a near threefold increase on the flow at Collarenebri. Annual flows are also decreasing generally over the long term at Bourke, although to a lesser degree than in the upper reaches (Figure 9).

In the lower reaches of the Darling River at Wilcannia, flows vary considerably from year to year, with a greater number of years when flow has been above the mean annual flow (Figure 10). Mean annual flow at Wilcannia is 2,304,741 ML, a third less than the mean annual flow at Bourke.

Figure 11 presents daily flows for the Darling River at Bourke. Considerable variability in daily flows is evident as are the major floods of the 1950s and 1970s. Moderate to major floods occur at an average frequency of every 8-10 years.

Low, median and high daily flows for the upper (Collarenebri), middle (Bourke) and lower (Wilcannia) reaches of the Barwon-Darling River are presented in Figure 12. High flows are represented by the 20th percentile flow, median (or middle value) by 50th percentile flows, and low flows are represented by 80th percentile flows.

High flows along the Barwon-Darling River are more frequent in late summer and early autumn. At Wilcannia high flows peak again in late winter and spring as a result of inflows from the southern tributaries. Month to month variation in daily flows occurs to a lesser extent for median flows, though is slightly more evident in the lower section of the river. Median daily flow in summer is up to 1000 ML/d at Collarenebri, and around 4,000 ML/d at Bourke and Wilcannia. The lowest flows occur in May-June for the upper half of the river, and June-July at Wilcannia.
Figure 12: High, median and low daily flows in the Barwon-Darling catchment

Source: Crown Lands & Water Division
3 Environmental assets

3.1 Parks and reserves

Approximately 3,930 km² of land is conserved within nature reserves, national park, and state conservation areas along the Barwon-Darling River (Table 4). The majority of these are located on the Darling River.

Located midway between Collarenebri and Walgett, Barwon Nature Reserve and Barwon State Conservation Area (SCA) are the only reserves along the 700 km of Barwon River. Barwon Nature Reserve has 2 km of frontage to the Barwon River and frontage to Thalaba Creek. Both reserves were former pastoral properties with the previously grazed areas now regenerating to naturalised grassland and chenopod shrubland. Despite their grazing history both properties retain extensive, high-quality riverine ecosystems. Barwon Nature Reserve is almost entirely comprised of the endangered ecological community Coolibah – Black Box Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain and Mulga Lands Bioregions (OEH 2014b).

Paroo-Darling National Park is the largest conservation reserve within and adjacent to the WRPA, covering an area of 1,781 km². It occurs at the junction of the Darling and Paroo rivers, including frontage to the north and south sides of the Darling River upstream of Wilcannia. Fifty-five bird species have been identified in the park and more than 60,000 waterbirds have been observed during surveys on some of the large lakes within the park. Threatened species found within the park include the pink cockatoo, red-tailed black-cockatoo, brolga, freckled duck and slender Darling pea (NPWS 2012).

Gundabooka National Park south of Bourke takes in 639 km² of the rugged Gundabooka Range and includes frontage to the Darling River. The mountain range is a significant place for the Ngemba and Paakandji Aboriginal people of western New South Wales and includes important ceremonial sites and rock art. The park conserves a variety of open woodland communities including mulga, poplar box, red box, ironwood, cypress pine, belah and leopardwood.

On the north side of the river, downstream of Bourke, Toorale National Park also features extensive frontage to the Darling River. The former pastoral property is located at the junction of the Darling and Warrego rivers and conserves vast areas of floodplain and wetland habitat. The property was purchased by the NSW Government in 2008 and includes significant aboriginal and pastoral heritage sites.

Table 4: Reserves along the Barwon-Darling River

<table>
<thead>
<tr>
<th>Reservation</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barwon State Conservation Area</td>
<td>5,243</td>
</tr>
<tr>
<td>Barwon Nature Reserve</td>
<td>4,048</td>
</tr>
<tr>
<td>Gundabooka State Conservation Area</td>
<td>25,200</td>
</tr>
<tr>
<td>Gundabooka National Park</td>
<td>63,903</td>
</tr>
<tr>
<td>Paroo-Darling State Conservation Area</td>
<td>41,521</td>
</tr>
<tr>
<td>Paroo-Darling National Park</td>
<td>178,053</td>
</tr>
<tr>
<td>Kinchega National Park</td>
<td>44,259</td>
</tr>
<tr>
<td>Toorale National Park</td>
<td>30,866</td>
</tr>
</tbody>
</table>

Source: DEWHA 2010, MDBA 2017
3.2 Wetlands

The Barwon-Darling WRPA consists only of the river channel itself. However there are many important and extensive wetlands that are located adjacent to the Plan area along the Barwon-Darling floodplain. Kingsford et al. (2003) identified 581,135 ha of wetlands across the Barwon-Darling River catchment covering 5 per cent of the catchment area. This wetland area includes 140 freshwater lakes covering 130,730 ha (22 per cent of wetland area) and 450,405 ha of floodplain wetlands (78 per cent of wetland area).

Significant wetlands adjacent to the Barwon-Darling River are listed in Table 5. These lakes and wetlands when inundated are habitat for large numbers of water birds, including migratory birds (DEWHA 2010). Poopelloe Lake, Talyawalka Creek and Pelican Lake within the Talyawalka-Teryawynya system, as well as the Darling River floodplain near Louth, are all areas known or predicted to support 20,000 or more waterbirds (Kingsford et al. 1997). The extensive Talyawalka-Teryawynya anabranch system leaves the Darling River south of Wilcannia. When flooded the lakes provide habitat for roosting, nesting and foraging waterbirds.

Table 5: Wetlands occurring in the Barwon-Darling WRPA

<table>
<thead>
<tr>
<th>Wetland site</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ngemba Billabong (Indigenous protected area)</td>
<td>Barwon River at Brewarrina</td>
</tr>
<tr>
<td>Acres Billabong</td>
<td>South side of the Darling River near Tilpa</td>
</tr>
<tr>
<td>Wongalara Lake</td>
<td>South side of the Darling River upstream of Wilcannia</td>
</tr>
<tr>
<td>Poopelloe Lake</td>
<td>South side of the Darling River upstream of Wilcannia</td>
</tr>
<tr>
<td>Lake Woytchugga</td>
<td>North side of the Darling River near Wilcannia</td>
</tr>
<tr>
<td>Talyawalka Anabranch and Teryawynya Ck (nationally important wetlands)</td>
<td>Leaves the Darling River downstream of Wilcannia</td>
</tr>
<tr>
<td>Menindee Lakes (nationally important wetlands)</td>
<td>Menindee</td>
</tr>
</tbody>
</table>

Source: DEWHA 2010, MDBA 2017
3.3 High ecological value aquatic ecosystems
The High Ecological Value Aquatic Ecosystem (HEVAE) framework consists of five key criteria (diversity, distinctiveness, naturalness, vital habitat and representativeness) for mapping and prioritising aquatic assets for water management (Aquatic Ecosystems Task Group 2012). The HEVAE framework was applied by DPI Water to assign an ecological value to instream assets across NSW using four of the five criteria (the representativeness criteria was not used due to insufficient data).

Figure 13 shows the value rating assessed for instream aquatic ecology of the Barwon-Darling River. Overall the ecological value of the Barwon-Darling River is assessed as medium to high, with the higher value sections of river occurring mostly in the upstream reach along the Barwon River. The river is assessed as having low distinctiveness (rarity/threatened/unusual), with the exception of the upper reaches of Barwon River. The Darling River is assessed as having a high diversity of species, habitats, and geomorphology, compared to the Barwon River which is considered to have medium habitat diversity.

Much of the Barwon-Darling River has been extensively modified by human disturbance resulting in either highly modified or intermediate scores for naturalness. In the vicinity of the Warrego River and Paroo River confluences, however, the Darling River has been subject to minimal human disturbance. In terms of vital habitat value, the Barwon River is assessed as having high or very high value for the survival of specific flora and fauna species, while the Darling River provides little if any habitat that is considered critical habitat.

The distribution of threatened fish species is shown in Figure 14. Four threatened fish species, with varying distribution have been observed in the Barwon-Darling River. Murray cod (Maccullochella peelii) is observed along the entire length of the Barwon-Darling River, as is olive perchlet (Ambassis agassizii), although observed infrequently. Silver perch (Bidyanus bidyanus) is observed along the entire length of the Barwon River and in the upper reaches of the Darling River. Eel-tailed catfish (Tandanus tandanus) was rarely observed, with only a single observation on the Darling River above Tilpa.

Figure 15 indicates the distribution of endangered ecological communities in the Barwon-Darling WRPA. Four endangered ecological communities (EEC) are known to occur on the Barwon-Darling River. The Lowland Darling River EEC is predicted to occur along the entire length of the Barwon-Darling River. Carbeen Open Forest Community occurs in the upper reaches of Darling River and the Barwon River. Marsh Club-rush sedgeland EEC occurs in the upper reaches of the Barwon River. Coolibah-Black Box Woodland occurs along the entire length of the Barwon River, and most of the Darling River.

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2 A threatened species is a species listed as endangered, critically endangered, or vulnerable under the NSW Threatened Species Conservation Act 1995.
3 Endangered ecological communities are ecological communities (an assemblage of species occupying a particular area) listed as endangered under the NSW Threatened Species Conservation Act 1995.
Figure 13: Instream values for the Barwon-Darling WRPA

Source: Crown Lands & Water Division

Figure 14: Distribution of threatened fish species within the Barwon-Darling WRPA

Source: Crown Lands & Water Division
3.4 Environmental water requirements for the Barwon-Darling River

To determine the sustainable diversion limit (SDL) for the Barwon-Darling River, the MDBA estimated the environmental water requirements for the Barwon-Darling River. For this purpose the MDBA defined the environmental asset as the Barwon-Darling River upstream of Menindee Lakes to Mungindi, including the Talyawalka Anabranch and Teryaweynya Creek system.

Environmental water requirements are flow requirements necessary to maintain two broad ecosystem functions of the environmental asset: longitudinal connectivity and lateral connectivity (MDBA 2016). Longitudinal connectivity relates to flow connections along the river riparian zone that link a “diversity of aquatic environments for feeding, breeding, dispersal, migration and re-colonisation by native aquatic species; and facilitate geomorphic processes, sediment and nutrient spiralling.” (MDBA 2016, p.5) Lateral connectivity refers to flow connections between “water courses and adjacent floodplains and wetlands that link a diversity of aquatic environments for feeding, breeding, migration and re-colonisation of native vegetation; and facilitate off-stream primary production, and nutrient and organic matter exchange.” (MDBA, 2016, p. 6)

Three flow components were then established for each of the two ecosystem functions; in-channel freshes, bank full flows and over bank flows. For each of these flow components, four flow parameters or indicators were adopted to describe flow requirements: magnitude, duration, timing and frequency. The flow parameters were then referenced to one or more flow gauges. Table 6 summarizes the flow requirements for the Barwon-Darling River as estimated by the MDBA.
3.5 Hydrologic Indicator Sites

The hydrologic indicator site approach uses detailed eco-hydrological assessment of environmental water requirements for a subset of key environmental assets and key ecosystems functions across the Basin (MDBA, 2012a). The environmental assets of the Barwon-Darling River upstream of Menindee Lakes are one of the key hydrologic indicator sites where a detailed assessment was undertaken. Through assessment of the environmental water requirements, the MDBA has determined the “Environmental Sustainable Level of Take” (ESTL) for the Barwon-Darling River upstream of Menindee (MDBA, 2012a). The ESTL is a representation of the Sustainable Diversion Limit (SDL); which is the maximum long-term annual average volumes of environmentally sustainable surface water that can be taken from the Basin for consumptive use.

The Barwon-Darling River between Mungindi and the Menindee Lakes contain 3 distinctive zones, each of which has at least one of the six hydrologic indicator sites herein. The three zones are:

1. the Anabranch zone, which extends between Mungindi to Collarenebri;
2. the Billabong zone which is located between Collarenebri and Bourke; and
3. the Basin zone from Bourke down to Menindee Lakes (MDBA, 2012a).

The natural morphology of the Barwon-Darling River provides a multitude of habitats for a range of species. Geomorphic features such as deep channels, deep pool areas, suspended load depositional ‘benches’, higher floodplain ‘benches’, braided channels, terminal wetland complexes, gravel beds and riffle zones (MDBA, 2012a) support large numbers of fish species, waterbird populations and black box (*Eucalyptus largiflorens*) and river red gum (*E. camaldulensis*) communities (MDBA, 2012a). The Barwon-Darling River upstream of Menindee met all five criteria used by the MDBA for determining a key environmental asset in the Basin. The wetlands are formally recognised in international agreements; they are natural or near-natural; they provide essential ecosystem habitat; they support state and national threatened species communities; and they are capable of supporting significant biodiversity (MDBA, 2012a).

“Detailed environmental water requirements led to the specification of site-specific flow indicators to achieve site-specific ecological targets” (MDBA 2012a, p.2). The site specific flow indicators are referenced to a “hydrologic indicator” site or sites. The hydrologic indicator sites, and flows describe at those sites, are intended to represent the broader environmental flow needs of river valleys or reaches (MDBA 2012b). The MDBA identifies five “ecologically significant components of the flow regime”. These components are “cease to flow periods”, “base flows (low flows)”, “freshes”, “full bank flows”, and “overbank flows” (MDBA 2012b, p.21). Freshes are considered as flows that exceed the upper limit of based flows yet below “bank full flows”. Overbank flows are flows that exceed bank full flows. The assessment for unregulated catchments attended primarily to base flow requirements (low flows) “reflecting the prioritisation of efforts on parts of the flow regime that are most sensitive to the determination of [environmental sustainable levels of take and sustainable diversion limits]” (MDBA 2012b, p.39).
Table 6: Summary of environmental flow requirements Barwon-Darling River

<table>
<thead>
<tr>
<th>Barwon-Darling ecological target</th>
<th>Ecosystem function</th>
<th>Flow gauge</th>
<th>Magnitude (ML/d)</th>
<th>Duration (days)</th>
<th>Timing</th>
<th>Frequency low uncertainty</th>
<th>Frequency high uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide a flow regime which:</td>
<td>Longitudinal connectivity (small fresh)</td>
<td>Bourke</td>
<td>6,000</td>
<td>14</td>
<td>Minimum of 1 event at any time of year</td>
<td>90% of years (with at least 1 event)</td>
<td>80% of years (with at least 1 event)</td>
</tr>
<tr>
<td>• Supports recruitment for native species</td>
<td>Longitudinal connectivity (small fresh)</td>
<td>Louth</td>
<td>6,000</td>
<td>20</td>
<td>Minimum of 1 event between Aug-May</td>
<td>70% of years (with at least 1 event)</td>
<td>70% of years (with at least 1 event)</td>
</tr>
<tr>
<td>• Supports waterbird habitat</td>
<td>Longitudinal connectivity (small fresh)</td>
<td>Wilcannia</td>
<td>6,000</td>
<td>7</td>
<td>Minimum of 2 events at any time of year</td>
<td>60% of years (with at least 1 event)</td>
<td>45% of years (with at least 1 event)</td>
</tr>
<tr>
<td>• Sustains current extent of native vegetation</td>
<td>Longitudinal connectivity (large fresh)</td>
<td>Bourke</td>
<td>10,000</td>
<td>14</td>
<td>Minimum of 1 event between Aug-May</td>
<td>80% of years (with at least 1 event)</td>
<td>60% of years (with at least 1 event)</td>
</tr>
<tr>
<td>• Supports longitudinal and lateral connectivity</td>
<td>Longitudinal connectivity (large fresh)</td>
<td>Bourke</td>
<td>10,000</td>
<td>20</td>
<td>Minimum of 2 events between Aug-May</td>
<td>70% of years (with at least 1 event)</td>
<td>45% of years (with at least 1 event)</td>
</tr>
<tr>
<td></td>
<td>Longitudinal connectivity (large fresh)</td>
<td>Louth</td>
<td>21,000</td>
<td>20</td>
<td>Minimum of 1 event between Aug-May</td>
<td>40% of years (with at least 1 event)</td>
<td>40% of years (with at least 1 event)</td>
</tr>
<tr>
<td></td>
<td>Longitudinal connectivity (large fresh)</td>
<td>Wilcannia</td>
<td>20,000</td>
<td>7</td>
<td>Minimum of 1 at any time of year</td>
<td>60% of years (with at least 1 event)</td>
<td>45% of years (with at least 1 event)</td>
</tr>
<tr>
<td></td>
<td>Lateral connectivity (riparian zone)</td>
<td>Bourke</td>
<td>30,000</td>
<td>24</td>
<td>Minimum of 1 at any time of year</td>
<td>2 years (average period between events)</td>
<td>3 years (average period between events)</td>
</tr>
<tr>
<td></td>
<td>Lateral connectivity (inner floodplain)</td>
<td>Bourke</td>
<td>45,000</td>
<td>22</td>
<td>Minimum of 1 at any time of year</td>
<td>3.5 years (average period between events)</td>
<td>4 years (average period between events)</td>
</tr>
<tr>
<td></td>
<td>Lateral connectivity (mid floodplain)</td>
<td>Bourke</td>
<td>65,000</td>
<td>24</td>
<td>Minimum of 1 at any time of year</td>
<td>6 years (average period between events)</td>
<td>8 years (average period between events)</td>
</tr>
<tr>
<td></td>
<td>Lateral connectivity (outer floodplain)</td>
<td>Wilcannia</td>
<td>2,350 (GL)</td>
<td>&gt;60</td>
<td>Minimum of 1 at any time of year</td>
<td>10% of years (with at least 1 event)</td>
<td>7% of years (with at least 1 event)</td>
</tr>
</tbody>
</table>

Source: MDBA 2016
4 Water quality

Degradation of water quality can put stress on a range of aquatic organisms, affect Aboriginal cultural and spiritual uses of water, increase the cost of drinking water treatment, contribute to public health risks, and decrease the suitability of water for irrigation.

Water quality in the Barwon-Darling WRPA varies from poor to good. The water quality status map (Figure 16) provides an overview of water quality for seven sites within the Plan area. Water quality condition index scores are an integrated indicator of total nitrogen, total phosphorus, pH, turbidity and dissolved oxygen at main monitoring locations in the plan area. The scores were calculated using the frequency and amplitude of exceedance of water quality targets listed in the Basin Plan between the years 2010-11 and 2014-15. Specific indices were also included for thermal pollution, harmful algal blooms, and salinity for irrigation water.

Water quality problems occurring within the catchment are mostly caused by a combination of alteration to natural flow regimes and land use change (DPI Water 2016a). The water quality management plan to be prepared as part of the water resource plan will provide further information on the water quality issues in the Barwon-Darling WRPA and may include possible management strategies.

Further information on the water quality of the Upper and Middle-Lower sections of the Barwon-Darling River is provided in the following sections.

Figure 16: Water quality condition for aquatic ecosystems of the Barwon-Darling WRPA

WaQI Scores: Blue = Excellent (100-95), Green = Good (94-80), Orange = Fair (79-60), Red = Poor (59-1).

Source: Crown Lands & Water Division
4.1 Upper Darling

In the upper reaches of the WRPA the water quality was assessed as being either fair or good for all sites. Dissolved oxygen was frequently below the target limit and unpredictable during low flows. It can sometimes be elevated due to algal growth. The pH is mostly within the target range and salinity is generally low. Salinity is occasionally elevated in the Barwon River at Brewarrina during times of low flow.

Nutrients (nitrogen and phosphorus) and suspended sediments were mostly within the target ranges but both can increase during high flows. Turbidity levels at all sites are high due to a number of factors including changes in land use, riparian condition, the presence of carp and land management practices. Fine clay particles remain in suspension in the water column even during low flows which results in elevated turbidity levels.

Harmful algal blooms may occur during the warmer months. They most commonly occur in weir pools such as at Collarenebri, Walgett and Brewarrina. They are caused by the combination of low flows, warm water and high nutrient levels.

4.2 Middle-Lower Darling

Water quality on the Darling River below Bourke is generally assessed as being poor. Dissolved oxygen is frequently below the target range, but may sometimes be elevated due to algal growth. The pH is frequently above the upper target limit, and may also become elevated during algal blooms. Salinity is generally low, except for the reach of river between Bourke and Louth where salinity is elevated.

Nutrients (nitrogen and phosphorus) were generally high throughout the zone and elevated particularly during high flows. Suspended sediments exceed the targets due to the inputs from the upper catchment and the suspension of fine clay particles within the water column. Algal blooms may occur within this zone during the warmer months, most commonly in weir pools such as Bourke, Louth and Tilpa.

The Barwon-Darling River is not affected by thermal pollution due to the lack of large storages on the river.
5 Riparian and geomorphic condition

Riparian vegetation is a key attribute connecting rivers and terrestrial ecosystems, controlling river bank stability, mitigating runoff, influencing instream processes, and providing habitat for a range of biota (Lovett and Price 2007). Leaf litter derived from riparian vegetation is a key contributor of allochthonous energy sources into rivers, driving primary production and stimulating the development of food chains (Robertson et al. 1999; Westhorpe et al. 2010). Native riparian vegetation cover greater than 60 per cent and a riparian buffer zone width of up to 30 metres are considered important to influencing good riparian condition (Jansen et al. 2003). An increase in the presence of large woody debris within rivers has been correlated with an increase in riparian tree cover, reaching a maximum when tree cover reaches 60 per cent (Matheson and Thoms 2017). Large woody debris derived from the riparian zone was associated with primary control on geomorphic stability and habitat heterogeneity in rivers (Brooks and Brierley 2002; Treadwell et al. 2007).

Changes to riparian vegetation can reduce the geomorphic condition of rivers (Brierley and Fryirs 2005). Reduction in geomorphic condition from good to moderate can be linked to reductions in macrophyte and macroinvertebrate assemblages (Chessman et al. 2006a), and freshwater mussel abundance declined in river reaches where geomorphic condition was reduced (Jones and Byrne 2010).

River Styles® recovery potential is synonymous with geomorphic condition. Recovery potential represents geomorphic stability and can indicate the capacity of a stream to return to good condition or to a realistic rehabilitated condition (Brierley and Fryirs 2005). Streams rated as having conservation or rapid recovery potential are likely to be the most stable and in a good condition, whereas streams with low recovery potential may never recover to a natural condition or may continue to decline quickly without intervention (Cook and Schneider 2006). Figure 17 and Figure 18 provide a general overview of riparian and geomorphic condition for the Barwon-Darling WRPA. Extensive clearing of riparian vegetation has occurred along the entire length of the Darling River, reflected in the medium to very low percentage coverage of native woody riparian vegetation (Figure 17). Medium to high coverage of riparian vegetation occurs in the lower and middle reaches of the Barwon River, while high to very high coverage occurs in the upper reaches of the river.

The potential for the Barwon-Darling River to recover from human disturbance is indicated on Figure 18. Most of the Darling River is considered to have a moderate potential for recovery. The Barwon River is assessed as being of high conservation value with regard to geomorphic condition, meaning that the morphology of the river is in near natural and stable condition. A small reach of the river upstream of Walgett is considered to have high recovery potential which could rapidly recover with appropriate land management (Figure 18).
Figure 17: Percent cover of native

Source: Crown Lands & Water Division

Figure 18: Geomorphic recovery potential in streams in the Barwon-Darling WRPA

Source: Crown Lands & Water Division
6 River operations and management

6.1 Storages and regulating structures

Although Barwon-Darling River is not a “regulated” river, regulated rivers in NSW contribute 70 per cent of flow in Barwon-Darling River (Table 3). The main NSW and Queensland headwater storages that regulate tributary flows are listed in Table 7. These storages were constructed within the period 1960-1987 and together have a combined storage capacity of 5,231,000 ML.

Numerous weirs have been constructed along the entire length of the river to provide temporary storage pools for irrigation and town water supplies (Table 8 and Figure 19). The construction of these weirs was authorised by the Darling River Weirs Act 1945 as follows:

“The construction of weirs of the fixed crest type without provision for navigation in the Barwon and Darling Rivers between the 29th parallel of south latitude and the confluence of the Darling River with the Murray River, together with works incidental thereto, such weirs to be not less than thirty and not more than forty in number and to be so located as to provide, in so far as is practicable, a continuous series of weir pools throughout the full length of the said rivers.” Darling River Waters Act, Act No.27, 1945.

A number of large off-river storages have also been constructed on private properties and have an estimated combined capacity of 284 GL (CSIRO 2008).

Table 7: Major headwater storages summary

<table>
<thead>
<tr>
<th>Storage</th>
<th>River</th>
<th>Capacity (ML)</th>
<th>Purpose</th>
<th>Nearest Town</th>
</tr>
</thead>
<tbody>
<tr>
<td>New South Wales</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burrendong Dam</td>
<td>Macquarie River</td>
<td>1,678,000</td>
<td>Irrigation, town water</td>
<td>Wellington</td>
</tr>
<tr>
<td>Copeton Dam</td>
<td>Gwydir River</td>
<td>1,364,000</td>
<td>Irrigation, town water</td>
<td>Bingara</td>
</tr>
<tr>
<td>Keepit Dam</td>
<td>Namoi River</td>
<td>423,000</td>
<td>Irrigation, town water</td>
<td>Gunnedah</td>
</tr>
<tr>
<td>Split Rock Dam</td>
<td>Manilla River</td>
<td>397,000</td>
<td>Irrigation, town water</td>
<td>Manilla</td>
</tr>
<tr>
<td>Windamere Dam</td>
<td>Cudgegong River</td>
<td>368,000</td>
<td>Irrigation, town water</td>
<td>Mudgee</td>
</tr>
<tr>
<td>Pindari Dam</td>
<td>Severn River</td>
<td>312,000</td>
<td>Irrigation, town water</td>
<td>Ashford</td>
</tr>
<tr>
<td>Chaffey Dam</td>
<td>Peel River</td>
<td>62,000</td>
<td>Irrigation, town water</td>
<td>Tamworth</td>
</tr>
<tr>
<td>Queensland</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glenlyon Dam</td>
<td>Pike Creek</td>
<td>261,000</td>
<td>Irrigation</td>
<td>Texas</td>
</tr>
<tr>
<td>Leslie Dam</td>
<td>Sandy Creek</td>
<td>108,000</td>
<td>Irrigation, town water</td>
<td>Warwick</td>
</tr>
<tr>
<td>Beardmore Dam</td>
<td>Balonne River</td>
<td>101,000</td>
<td>Irrigation, town water supply</td>
<td>St George</td>
</tr>
<tr>
<td>Cressbrook Dam</td>
<td>Cressbrook Creek</td>
<td>81,800</td>
<td>Irrigation, town water</td>
<td>Toowoomba</td>
</tr>
<tr>
<td>Coolmunda Dam</td>
<td>Macintyre Brook</td>
<td>75,200</td>
<td>Irrigation, town water</td>
<td>Inglewood</td>
</tr>
</tbody>
</table>

Source: Crown Lands & Water Division
<table>
<thead>
<tr>
<th>Weir</th>
<th>River</th>
<th>Nearest town</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mungundi Weir</td>
<td>Barwon</td>
<td>Mungundi</td>
</tr>
<tr>
<td>Comilaroy Weir</td>
<td>Barwon</td>
<td>Mungundi</td>
</tr>
<tr>
<td>Barnaway Weir</td>
<td>Barwon</td>
<td>Collarenebri</td>
</tr>
<tr>
<td>Weir No. 8</td>
<td>Barwon</td>
<td>Collarenebri</td>
</tr>
<tr>
<td>Collarenebri Weir</td>
<td>Barwon</td>
<td>Collarenebri</td>
</tr>
<tr>
<td>Weir No.10 (Woorawadian)</td>
<td>Barwon</td>
<td>Walgett</td>
</tr>
<tr>
<td>Weir No. 11A (Walgett)</td>
<td>Barwon</td>
<td>Walgett</td>
</tr>
<tr>
<td>Brewarrina Weir</td>
<td>Barwon</td>
<td>Brewarrina</td>
</tr>
<tr>
<td>Bourke Weir</td>
<td>Darling</td>
<td>Bourke</td>
</tr>
<tr>
<td>Weir 19A</td>
<td>Darling</td>
<td>Bourke</td>
</tr>
<tr>
<td>Weir 20A</td>
<td>Darling</td>
<td>Louth</td>
</tr>
<tr>
<td>Louth Weir</td>
<td>Darling</td>
<td>Louth</td>
</tr>
<tr>
<td>Tilpa Weir</td>
<td>Darling</td>
<td>Tilpa</td>
</tr>
<tr>
<td>Wilcannia Weir</td>
<td>Darling</td>
<td>Wilcannia</td>
</tr>
<tr>
<td>Menindee Main Weir</td>
<td>Darling</td>
<td>Menindee</td>
</tr>
</tbody>
</table>

Source: Crown Lands & Water Division

Figure 19: Location of major weirs and regulators in the Barwon-Darling WRPA

Source: Crown Lands & Water Division
6.2 Licensed water shares and extraction

6.2.1 Barwon-Darling share components

A total of 181,102 ML of licence shares (approximately 200 water licences) were held within the Barwon-Darling WRPA at the commencement of the water sharing plan in 2012 (Table 9). The majority of these licence shares are for irrigation purposes (unregulated river licences). Approximately three per cent of shares (5,400) are held by local water utilities for town water supply purposes. Six town water supplies are located along the length of the Barwon-Darling River; Collarenebri town water supply, Walgett, Brewarrina, North Bourke, Bourke, Louth and Wilcannia town water supply (DPI Water 2012).

The majority of shares are held in the upper reaches of Darling River and along the length of Barwon River (Figure 21). The water sharing plan for Barwon-Darling River establishes an estimated total non-licensed water requirement for domestic and stock rights of 1.047 ML/day.

Table 9: Surface water share components for the Barwon-Darling River as 1 July 2012

<table>
<thead>
<tr>
<th>Access licence category</th>
<th>Total shares</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic and Stock</td>
<td>2,660</td>
</tr>
<tr>
<td>Local water utility</td>
<td>5,404</td>
</tr>
<tr>
<td>Supplementary (Aboriginal environmental)</td>
<td>0</td>
</tr>
<tr>
<td>Unregulated river (A class)</td>
<td>8,996</td>
</tr>
<tr>
<td>Unregulated river (B class)</td>
<td>119,288</td>
</tr>
<tr>
<td>Unregulated river (C class)</td>
<td>44,754</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>181,102</strong></td>
</tr>
</tbody>
</table>

Source: Crown Lands & Water Division

6.2.2 Barwon-Darling licensed extraction

Extraction from the Barwon-Darling River accounts for around three per cent of all surface water diverted across the Murray-Darling Basin (CSIRO 2008). The majority of water is used for irrigation purposes. Estimated (modelled) average annual take of water from the Barwon-Darling River for the period 1996/97 to 2011/12 is 153 GL and has varied between 1 GL and 209 GL over this period (Figure 20).

Figure 20: Estimated extraction in the Barwon-Darling WRPA

Source: MDDBC 1998 and subsequent years.
Figure 21: Location of licence shares on the Barwon-Darling River

Source: Crown Lands & Water Division
6.3 Water trading

Permanent trades refer to the trade of share components between licences, while temporary trades refer to the trade of water allocations. The implementation of water sharing plans has removed barriers to the efficient operation of these water markets, facilitating more efficient and better informed trades. This has been achieved through the inclusion of clear rules for trading in water sharing plans, the separation of the water licence from the land title in 2004, and the establishment of public registers in 2004. Registers show the volume and price paid for access licences. The current price for water from the Barwon-Darling River is around $1100 per megalitre (Marsden Jacob Associates 2017).

The quantity of permanent trades in the Barwon-Darling for the period 2013 to 2017 is shown in Figure 22. Variations between years are mostly related to climatic conditions and the volume of water made available to different licence categories. Despite the Barwon-Darling River being an unregulated river, the acquisition of licence shares has occurred in most years for environmental purposes.

Figure 23 indicates the temporary trade of water allocations for the period 2013 to 2017. Trading activity is strongly linked to water availability. Almost no trading occurred in 2014 due to critically low river levels however the return of significant flows to the river in the second half of 2016 saw a significant increase in the volume of water traded between accounts during that year.

Figure 22: Permanent trades in the Barwon-Darling River from Jan 2013 to May 2017

![Figure 22: Permanent trades in the Barwon-Darling River from Jan 2013 to May 2017](Source: Crown Lands & Water Division)

Figure 23: Temporary trades in the Barwon-Darling River from Jan 2013 to May 2017

![Figure 23: Temporary trades in the Barwon-Darling River from Jan 2013 to May 2017](Source: Crown Lands & Water Division)
## Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquatic ecosystems</td>
<td>Ecosystems that are dependent on flows, or periodic or sustained inundation/waterlogging for their ecological integrity. Examples include wetlands, rivers, karst and other groundwater-dependent ecosystems, saltmarshes, estuaries and areas of marine water not exceeding 6 m deep at low tide.</td>
</tr>
<tr>
<td>Allocation</td>
<td>The volume of water assigned to water allocation accounts in a given season, defined according to rules in the relevant water plan.</td>
</tr>
<tr>
<td>Allocation assignment</td>
<td>The transfer of water between licence holder allocation accounts as a result of a trade agreement. The assignment becomes part of the receiver’s allocation account water for the current water year.</td>
</tr>
<tr>
<td>Available water determination (AWD)</td>
<td>A determination referred to in section 59 of the <em>Water Management Act 2000</em> that defines the proportion of the share component that will be available for extraction under each category of water access licence.</td>
</tr>
<tr>
<td>Basic Landholder Rights</td>
<td>Means domestic and stock rights, harvestable rights or native title rights.</td>
</tr>
<tr>
<td>Cold water pollution</td>
<td>An artificial decrease in the temperature of water in a natural river.</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>Measured concentration of oxygen dissolved in water.</td>
</tr>
<tr>
<td>Domestic consumption</td>
<td>Consumption of water for normal household purposes in domestic premises on the land.</td>
</tr>
<tr>
<td>Ecological value</td>
<td>The perceived importance of an ecosystem which is underpinned by the biotic and/or abiotic components and processes that characterise that ecosystem.</td>
</tr>
<tr>
<td>Ecosystem</td>
<td>A specific composition of animals and plants that interact with one another and their environment.</td>
</tr>
<tr>
<td>Ecosystem functions</td>
<td>The processes that occur between organisms and within and between populations and communities. They include interactions with the nonliving environment that result in existing ecosystems and bring about dynamism through changes in ecosystems over time.</td>
</tr>
<tr>
<td>Effluent</td>
<td>An effluent stream is one which leaves the main river and does not return.</td>
</tr>
<tr>
<td>Endangered ecological community</td>
<td>Ecological communities as listed in Schedule 1 of the <em>Threatened Species Conservation Act 1995</em> or Schedule 4 of the <em>Fisheries Management Act 1994</em>.</td>
</tr>
<tr>
<td>Eutrophication</td>
<td>The process where an accumulation of nutrients in water bodies leads to rapid growth of aquatic plants.</td>
</tr>
<tr>
<td>Farm dams</td>
<td>Private dams that are used to intercept catchment runoff that would otherwise contributed to streamflow or recharge of aquifers. Primarily located on hillsides (does not include floodplain harvesting dams).</td>
</tr>
<tr>
<td>General security licence</td>
<td>A category of water access licence implemented under the <em>Water Management Act 2000</em>. Forms the bulk of the water access licence entitlement volume in NSW and is a low priority entitlement i.e. only receives water once essential and high security entitlements are met in the available water determination process.</td>
</tr>
<tr>
<td><strong>Groundwater</strong></td>
<td>Water that occurs beneath the ground surface in the saturated zone.</td>
</tr>
<tr>
<td>-----------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Groundwater dependent ecosystems</strong></td>
<td>Ecosystems that require access to groundwater to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services.</td>
</tr>
<tr>
<td><strong>Harmful algal bloom</strong></td>
<td>An algal bloom that causes negative impacts to other organisms through the production of natural toxins, mechanical damage, or other means.</td>
</tr>
<tr>
<td><strong>High flows</strong></td>
<td>Also called bankfull events, these reshape the channel, creating habitats such as pools, bars and benches.</td>
</tr>
<tr>
<td><strong>High security licence</strong></td>
<td>A category of licence water access licence implemented under the <em>Water Management Act 2000</em>. Receives a higher priority than general security licences but less priority than essential requirements in the available water determination process.</td>
</tr>
<tr>
<td><strong>Instream value</strong></td>
<td>Ecological condition value of river reaches based upon High Ecological Value Aquatic Ecosystems (HEVAE). In NSW HEVAE was calculated using four criteria: distinctiveness, diversity, naturalness and vital habitat.</td>
</tr>
<tr>
<td><strong>Low flows</strong></td>
<td>Flows that are confined to the lower part of the channel; also often called base flows. These flows are between pools and riffle areas between pools. Generally defined as the 80th percentile flow.</td>
</tr>
<tr>
<td><strong>Nitrogen and phosphorous</strong></td>
<td>Chemical nutrients essential for growth and added to many fertilisers.</td>
</tr>
<tr>
<td><strong>Overbank flows</strong></td>
<td>High flows that connect the river to floodplain and wetlands allowing the exchange of nutrients and sediment to these areas.</td>
</tr>
<tr>
<td><strong>Regulated river</strong></td>
<td>Gazetted under the <em>NSW Water Management Act 2000</em> and is a river where downstream flows are regulated by a major state-owned storage. Downstream licence holders can order water against a held entitlement.</td>
</tr>
<tr>
<td><strong>Replenishment flows</strong></td>
<td>Flows provided along effluent systems to supply water for household, town use and stock.</td>
</tr>
<tr>
<td><strong>Riparian</strong></td>
<td>Relating to or living or located on the bank of a natural watercourse, such as a river stream.</td>
</tr>
<tr>
<td><strong>Salinity</strong></td>
<td>The concentration of sodium chloride or other dissolved minerals in water, usually expressed in EC units or milligrams of total dissolved solids per litre. Conversion factor is 0.64 mg/l TDS = 1000 μS/cm = 1 dS/m.</td>
</tr>
<tr>
<td><strong>Seasonality</strong></td>
<td>The timing of flooding and low flow events.</td>
</tr>
<tr>
<td><strong>Share component</strong></td>
<td>An entitlement to water specified on the access licence, expressed as a unit share or in the case of specific purpose licences, a volume in megalitres (e.g. local water utility, major water utility and domestic and stock).</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stock watering</td>
<td>The watering of stock animals being raised on the land but does not include the raising of stock animals on an intensive commercial basis that are housed or kept in feedlots or buildings for all (or a substantial period) during which the stock animals are being raised.</td>
</tr>
<tr>
<td>Stratification</td>
<td>The formation of separate water layers.</td>
</tr>
<tr>
<td>Supplementary water</td>
<td>Formerly known as off-allocation water, this is surplus flow resulting from storm events that cannot be captured in storages or weirs. When the water is not needed to meet current demands or commitments, then it is considered surplus to requirements and a period of Supplementary Access is announced. Supplementary Water Access Licence holders can only pump water against these licences during these announced periods. Other categories of licence holders may also pump water during these periods.</td>
</tr>
<tr>
<td>Water access entitlement</td>
<td>A water product (licence) issued under the Water Management Act 2000.</td>
</tr>
<tr>
<td>Water resource plan</td>
<td>A plan made under the Commonwealth Water Act 2007 that outlines how a particular area of the Murray–Darling Basin’s water resources will be managed to be consistent with the Murray–Darling Basin Plan. These plans set out the water sharing rules and arrangements relating to issues such as annual limits on water take, environmental water, managing water during extreme events and strategies to achieve water quality standards and manage risks.</td>
</tr>
<tr>
<td>Water sharing plan</td>
<td>A plan made under the Water Management Act 2000 which sets out the rules for sharing water between the environment and water users within whole or part of a water management area or water source.</td>
</tr>
<tr>
<td>Water source</td>
<td>The whole or any part of:</td>
</tr>
<tr>
<td></td>
<td>• one or more rivers, lakes or estuaries, or</td>
</tr>
<tr>
<td></td>
<td>• one or more places where water occurs naturally on or below the surface of the ground, and includes the coastal waters of the State.</td>
</tr>
</tbody>
</table>

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6 As defined in the Water Management Act 2000
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