Connectivity analysis methods for observed data in the Barwon-Darling and Lower Darling

A technical description of the cease-to-flow and low flow analysis methods applied for observed data in the Barwon-Darling and Lower Darling to support public release of that data and insights.

Report purpose

This report is intended to support the public release of historical flow data for key streamflow gauges on the Barwon-Darling. This river system has a few streamflow gauging sites that were installed in the 1800s. However, much of the earliest flow data are not generally available through the public facing WaterNSW real-time data web portal or through the internal Hydstra flow records data system.

For the purposes of the connectivity analysis work, this data was accessed from digitisation of archived paper-based records. DPIE-Water has agreed to publish this data.

This report describes how the data was manually inspected and of changes made to some of the data. The report is supported with published data sets .

Analysis purpose

To characterise connectivity in the Barwon-Darling and Lower Darling, the Water Analytics Unit of DPIE-Water was asked to investigate:

- How the frequency and duration of cease-to-flow and low flow events has changed over time.
- If the frequency and duration of cease-to-flow and low flow events has increased in recent years compared to the past.
- If there is a relationship between cease-to-flow and low flow periods with wet and dry climate cycles.
- The influences of increased irrigation development over time
- The expected impacts of projections of climate change.

In consultation with DPIE-Water's Regional Water Strategies team it was agreed that the analysis would:

- Use streamflow gauges at Walgett, Brewarrina, Bourke, Wilcannia and Weir32
- Report on the historical periods 1900s to 1950, 1950 to 2000 and post 2000
- Use operational advice from WaterNSW for equivalent cease-to-flow levels
- Use the resumption of flow rules to define low flows in the Barwon-Darling and Weir 32 minimum flow targets in the Lower Darling
- Compare modelled without development scenarios to an annual permitted take scenario to understand the effects of irrigation development.

- Use long term paleo-stochastic and NARCliM climate data sets to estimate the effects of projected climate change.

The following sections described the analysis undertaken on the observed data alone. The treatment of the modelled data is excluded.

Observed data quality inspection

Flows in rivers are not recorded directly – instead they are a derived figure. The raw data initially recorded is the height of the water surface above a reference benchmark. This is then converted to an estimate of flow based on a “rating curve” that relates height to flow.

The rating curve is created using the results of multiple gauging of streamflow where the cross section of the flow at an observed height is surveyed, and multiple direct measurements of flow velocity are made horizontally and vertically through this cross section. The velocities are multiplied by the cross-sectional areas to estimate flow for that height of water.

The relationship between flow and height is not always static. There is measurement inaccuracy in individual gaugings and some rating curves shift over time in response to changes in the channel cross section which affect hydraulics.

The quality of older records outside of the Hydstra flow data system is often reduced, for example which rating curve was applied, or how equipment breakdowns were addressed is often not recorded.

With this in mind, and with knowledge and experience of how flow varies in the Barwon-Darling from recent good quality data, all low flow periods were inspected and adjusted for the following common issues:

- Periods of unnaturally constant flow which may be equipment failure, such as a gauge that may have been stuck.
- Gauge zero errors where an inappropriate rating curve has been applied so that a period of zero-flow is instead showing as a period of very low flow.
- Missing data recorded as zero-flow.
- Sawtooth or block change periods of low and cease-to-flow where data is flipping between two discrete flow values.
- Implausible flow hydrograph shapes.

For all low flow and zero-flow periods the flows were plotted and visually inspected. Key visual cues are unnaturally flat flow periods, constant small flow values and unnatural flow event shapes or recessions. Where available, suspect flows were compared to upstream and downstream gauges for consistency.

A log file “*notes.csv*” is provided for each set of gauge data that records if each period is considered to be cease-to-flow along with a simple explanation.

Gap filling

All the gauges used contained periods of missing data. Where available, data from the nearest gauge was used to simply gap fill or extend the flows at the target site. Target gauge sites were not gap filled with other target sites to avoid double counting data quality issues.

This approach is reasonable for the purpose of analysing low flow and cease-to-flow events because the Barwon-Darling has almost no local catchment contributions. This means that flow gauges are very highly correlated, especially during low flow and cease-to-flow events when transmission loss and routing effects are not significant.

In simple terms, if an upstream gauge has no flow, then the next gauge downstream almost certainly also has no flow.

The Weir32 gauge commences in the 1960s. However, the Menindee Town gauge installed in the late 1880s is quite close, and for the purpose of this analysis data from the two sites was merged.

The gap filling and extensions applied are fit for this connectivity analysis purpose (cease-to-flow and low flows). The method may not be suitable and was not used to analyse other parts of the flow regime.

Cease-to-flow bias adjustment

The hydrologic condition of cease-to-flow is a subjective concept that is conditioned by the river function being considered by the end user. For example, a farmer may consider cease-to-flow to occur when pools are not being filled and water stagnates. A regulator may consider cease-to-flow to occur when they cannot see moving water with the naked eye. A fisherman may consider cease-to-flow to occur when targeted fish cannot move along the river.

Cease-to-flow can be assessed as literally a zero-flow recording at the gauge, but this can lead to unrealistic assessments due to small errors such as measurement uncertainty for very small height changes in weir pools, wind moving water in pools creating wave actions and so on.

Most analysis of cease-to-flow conditions apply a simple bias correction such that any recorded flows below a nominated figure are considered to be cease-to-flow for the purpose of that analysis.

A variety of values have been used in the past, but a short review identified no especially strong basis for any of them. We sought advice from WaterNSW operators, who are technical experts for these systems, and adopted their preferred values. These are listed in the following table.

Gauge Location	Cease-to-flow Threshold (ML/day)
Walgett	25
Brewarrina	20
Bourke	0
Wilcannia	20
Weir32	5
Pooncarrie	0
Burtundy	0

Bourke flow data quality and exclusion

We received Bourke flow data commencing in 1832 that appeared to be largely free of gaps. On closer inspection we found that the period 1832 to 1872 consisted of large flow events separated by very long apparent cease-to-flow events. It was concluded that these cease-to-flow periods were more likely missing data periods, and since the remaining data is only recording large flow events, the data was not useful to this study.

The period 1872 to 1892 is visibly different to the previous 40 years, but on closer review we concluded that although a wider range of flows was recorded, there was still no clear distinction between missing data and real periods of zero or low flows. This may be due to a change in gauge reader, or perhaps an intent to record a wider range of flow conditions.

An initial analysis showed major differences in the frequency of cease-to-flow events at Bourke in the first half of the record compared to flows at upstream and downstream gauges. Inconsistencies were also found in the rating curve being applied and the actual recorded heights when compared to nearby sites. A key finding was that cease-to-flows were occurring at Bourke but not at the other gauges. We could also see natural shaped recessions in the height data were being truncated as zero-flow after applying the rating curve.

Reviewing the history of the site identified that the original Bourke weir was constructed in 1892 and that until the 1940s the weir was an operable structure with varying pool levels, after which it was replaced with a concrete fixed crest weir. We are uncertain of the pre-1940 Bourke data because applying a fixed rating curve that does not consider weir operations will rarely produce plausible flows in the lower part of the flow regime, and we were unable to locate any records from the period to show either weir opening settings, or recorded flows from the period that considered the weir operations.

Without the pre-1940 data, the site was much less useful as a long-term record and we removed it from our analysis.

We acknowledge that the existence of a flow record as far back as 1832 is rare in the Murray-Darling Basin context and we are keen to locate other information that would allow us to better understand the Bourke data and how it might be used with certainty.