The Behaviour of Floods in Australia's Dryland Warrego River

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Key Points

- The aim of this study was to better understand flood behaviour as floods pass down the Warrego River from the upper catchment to the confluence with the Darling River
- All floods (n = 48) that occurred from 1993 to 2019 were tabulated and analysed to characterize the pattern of flood behaviour
- Analysis showed relatively strong flood peak and flood volume relationships for consecutive hydrological gauges, moving from north to south, down the Warrego River.
- Both the flood peak and volume were highly attenuated reducing by approximately 90% from the top gauge at Wyandra to the bottom gauge at Fords Bridge
- This study revealed that there was generally a predictable and consistent pattern of flood attenuation in the Warrego River during the study period

Abstract

The behaviour of floods in the Warrego River has been the centre of public conjecture. In particular, there has been speculation that flow into the Darling River has been reduced through upstream structures capturing water. The aim of this study was to better understand the behaviour of floods as they passed down the Warrego system over a 27-year period (1993 to 2019). Flood attenuation was analysed by tracking the downstream progression of headwater generated floods and calculating the change in peak and volume transmission as the floodwaters passed our selected gauges. A consistent pattern of downstream attenuation during the 27-year study period was identified. An anomalous period was also identified between May 1999 and September 2001 where the passage of eight floods was greatly reduced. Better understanding of the pattern of contribution of the Warrego River to the Darling River can help to broaden public understanding of the water sources in the Murray-Darling Basin.

Keywords

Warrego River, Dryland, Flood, Behaviour, Attenuation, Murray Darling Basin

Introduction

The behaviour of floods in the Warrego River has been the centre of public conjecture. In particular, there has been speculation that the passage of floods down the Warrego, into the Darling River has been altered in recent years. The aim of this study was to better understand flood passage (volume and peak) behaviour as floods pass down the Warrego system from the upper catchment to the confluence with the Darling River.

Regional setting and channel geomorphology

The Warrego River originates in the Carnarvon Ranges, Queensland, where is drains a catchment of ~75,000 km^2 and flows approximately 850 km in a southerly direction to its confluence with the Darling River downstream of Bourke, New South Wales (Figure 1; Larkin *et al.,* 2020). The Warrego catchment is subject to highly variable inter-annual rainfall with rain falling predominantly during summer. Across the catchment an average of 300-400 mm is received per year (Bureau of Meteorology, 2021).

The northern section of the Warrego system consists of several tributary streams that join to form a main single channel north of Wyandra (Figure 1). The reach described by the Wyandra and Cunnamulla gauges is largely a single channel meandering stream. Below Cunnamulla a distributary channel directs some flows to the Cuttaburra wetlands to the west and the remaining flows continue in a mainly southerly direction down the Warrego system to the confluence with the Darling River. Below Cunnamulla, the Warrego displays multiple small capacity flow paths with a main channel being difficult to discern in many reaches.

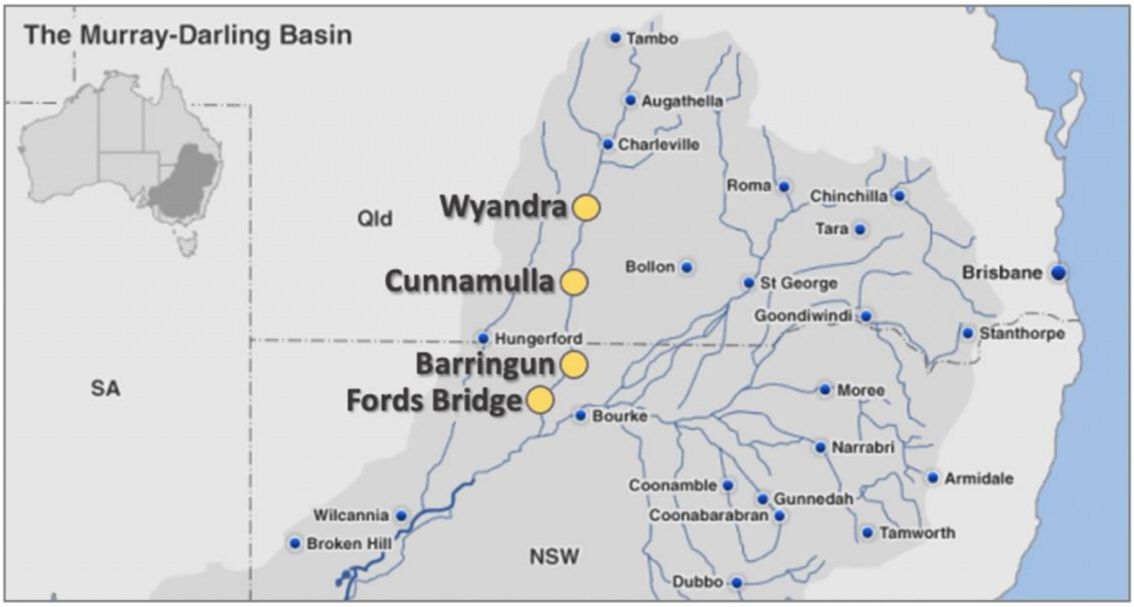

Figure 1 Location of the Warrego River in the Murray Darling Basin (MDB) as well as the location of gauges used for this study.

Methods

To examine flood passage behaviour, data from all of the main river gauges on the Warrego River were downloaded from the QLD and NSW waterinfo websites (Water Monitoring Information Portal, QLD, 2020; Real-time Data, NSW, 2020) and assessed for suitability for the study. The gauges at Wyandra, Cunnamulla, Barringun and Fords Bridge (main channel and bywash) were found to provide reliable data records over an approximate 27-year period (Table 1). Data from these gauges were downloaded and analysed for this study.

Hydrological data

Mean daily discharge (ML/d) data for the period between 01/06/1993 and 31/12/2019 were downloaded for the selected gauges (Table 1). Fords Bridge, at the southern extent of the Warrego catchment, hosts two separate gauges located on the main channel and the bywash channel. Data from this pair of gauges were combined to capture the total discharge at this site and will hereafter be called Fords Bridge.

Table 1 The five gauges along the Warrego channel that were used to analyse flood passage from 1993-2019.

State	Gauge location	Gauge number
QLD	Wyandra	423203A
QLD	Cunnamulla weir	423202A
NSW	Barringun	423004
NSW	Fords Bridge (a) Main channel (b) Bywash	(a) 423001 (b) 423002

Defining a flood

Thresholds were developed to identify unique flood events. These thresholds were developed considering the local channel and discharge conditions at each gauge based on examination of the hydrographs (Table 2;

Figures 2 and 3). Since the Wyandra gauge is upstream of the other gauges, floods were initially identified at this gauge and individual floods were tracked downstream to record flood peak and volume at each gauge. Floods were identified as periods of high discharge at Wyandra where discharge peaked over 5,000 ML/d. Floods were considered to be separate events when discharge fell below 100 ML/d for 7 consecutive days at each of the gauges. Using the Wyandra flood definition as the baseline to describe floods, a minimum flow peak and period of event separation was developed (Table 2). Three flood events were found to have been generated from mid-catchment rainfall at either Cunnamulla or Barringun rather than Wyandra. Data for these events were also extracted but comparison was only made with the respective downstream gauges.

As an example, Figure 4 shows the hydrograph for Wyandra and Cunnamulla from 10/2/1998-10/5/1999. In this hydrograph three separate flow events were identified for study using the designated 5,000 ML/d flood peak threshold for the Wyandra gauge.

These flood boundary parameters were used to identify 37 floods for study.

Table 1 The rules used to define a flood at each of the gauge sites used in this study.

Gauge location	Definition of: Flood event	Separate flood event
Wyandra	≥ 5,000 ML/day	≤ 100 ML/day for 7 consecutive days
Cunnamulla	≥ 4,000 ML/day	
Barringun	≥ 650 ML/day	
Fords Bridge		

While the selected thresholds to define floods were appropriate for most large flow events (Figure 2) some flood behaviour was complex with multiple peaks merging downstream and the flows between floods remaining unusually high for extended periods. For these events a modified set of event-specific rules was developed. Figure 3 shows the period from 25/11/1999 to 31/8/2000. In this period there were four clear flow peaks that exceeded the flood threshold. However, the flows between floods remained relatively high so to capture these floods in the analysis the minimum discharge level rule between floods was increased to the minimum discharge value between each of the flood peaks in the sequence. These modified rules were used to identify an additional 11 floods.

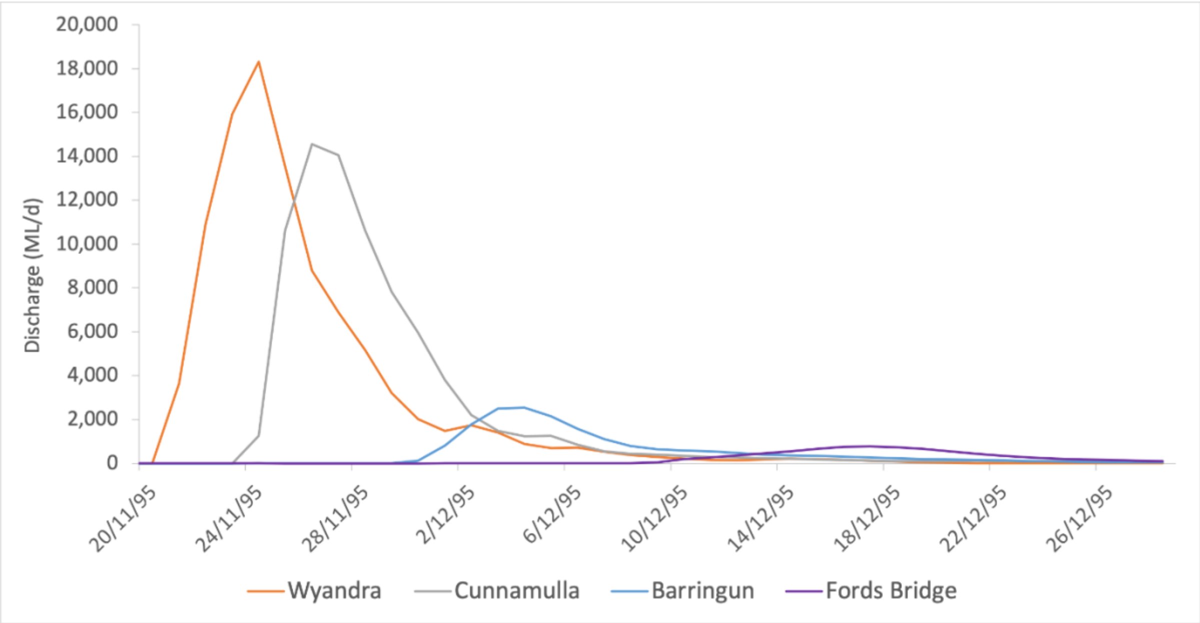

Figure 2 A well-defined flood event with the succession and attenuation of the flow peak and volume clearly evident when plotted on a hydrograph.

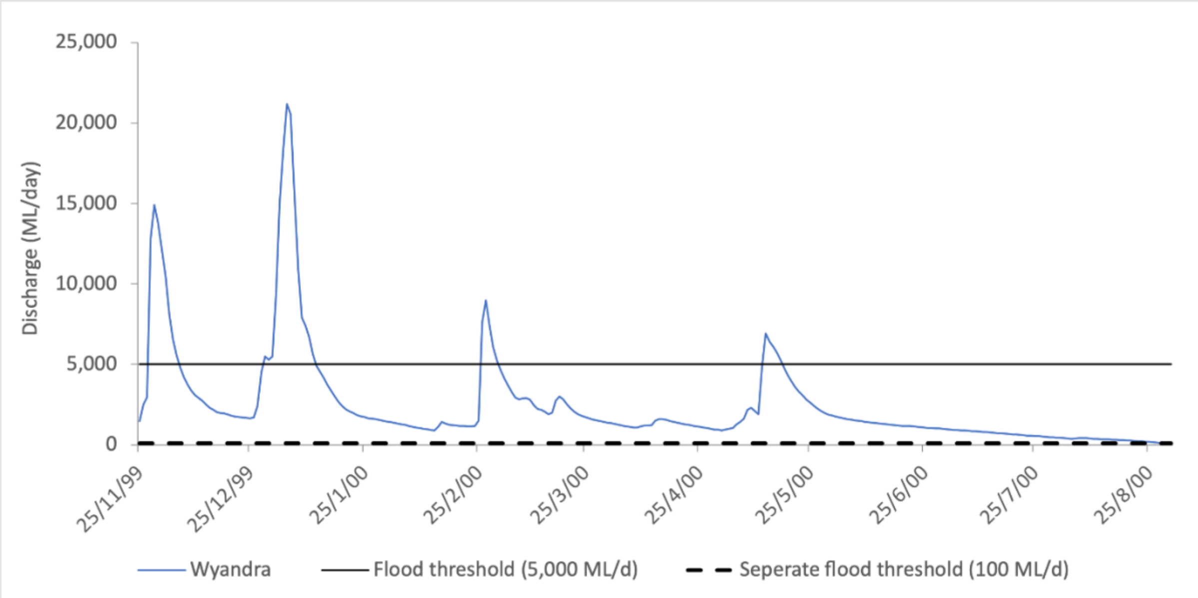

Figure 3 A series of flood events at Wyandra that were an exception to the flood threshold rules.

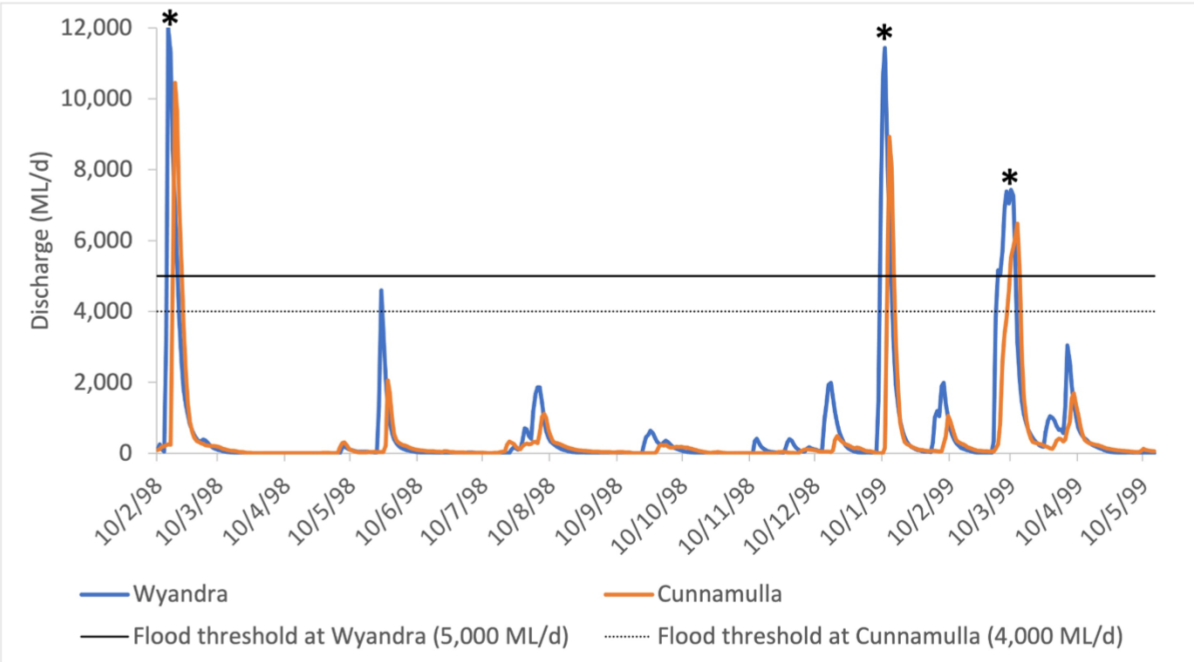

Figure 4 Hydrograph illustrating the flood thresholds of 5,000 ML/d and 4,000 ML/d for the Wyandra and Cunnamulla gauges, respectively. Asterix denote flows that were classified as floods as they exceeded the flood thresholds at their respective gauges.

Flood behaviour analysis

The peak and volume of all identified floods were tabulated and analysed. The behaviour of each flood was assessed by comparing the flood peak and volume as it moved downstream. Scatterplots were used to visualise the inter-gauge relationship and simple linear regression was calculated to describe the strength of the observed relationship. The pattern of flood behaviour was also described as a proportion of change between adjacent gauges.

Results

Flood behaviour analysis

A total of 48 floods were identified during the 27-year duration studied (1/6/1993-31/12/2019). The downstream progression of each flood was tracked via the hydrological gauges and the changes in flood peaks and volumes analysed.

Peak transmission

Nearly all floods analysed were found to originate upstream of Wyandra and decrease substantially in volume and discharge as they progressed downstream. Only three events were classified as floods at the Cunnamulla or Barringun gauges and not at the Wyandra gauge and these floods also attenuated as they moved downstream. The average percentage of flood peak (ML/d) transferred between consecutive gauges, from upstream to downstream, were as follows: Wyandra to Cunnamulla = 72%; Cunnamulla to Barringun = 16%; Barringun to Fords Bridge = 42%. In other words, the flood peak at Cunnamulla gauge was on average 72% that of the peak at Wyandra and so on. The average percentage of flood peak transferred from the top to the bottom of the catchment (Wyandra to Fords Bridge) was 7%.

Volume transmission

The average percentage of flood volume (ML/d) transferred between consecutive gauges, from upstream to downstream, were as follows: Wyandra to Cunnamulla = 74%; Cunnamulla to Barringun = 27%; Barringun to Fords Bridge = 58%. The average percentage of flood volume transferred from the top to the bottom of the catchment (Wyandra to Fords Bridge) was 13%.

Downstream flood peak correlation

Figure 5 shows the linear relationship of flood peaks at successive gauges with the strength of the simple linear relationship represented by the r-squared statistic. Analysis showed relatively strong flood-peak relationships for consecutive gauges with the r-squared values for peak attenuation as follows: Wyandra-Cunnamulla r^2=0.9; Cunnamulla-Barringun r^2=0.8; Barringun-Fords Bridge r^2=0.8; and the overall relationship from Wyandra-Fords Bridge r^2=0.6.

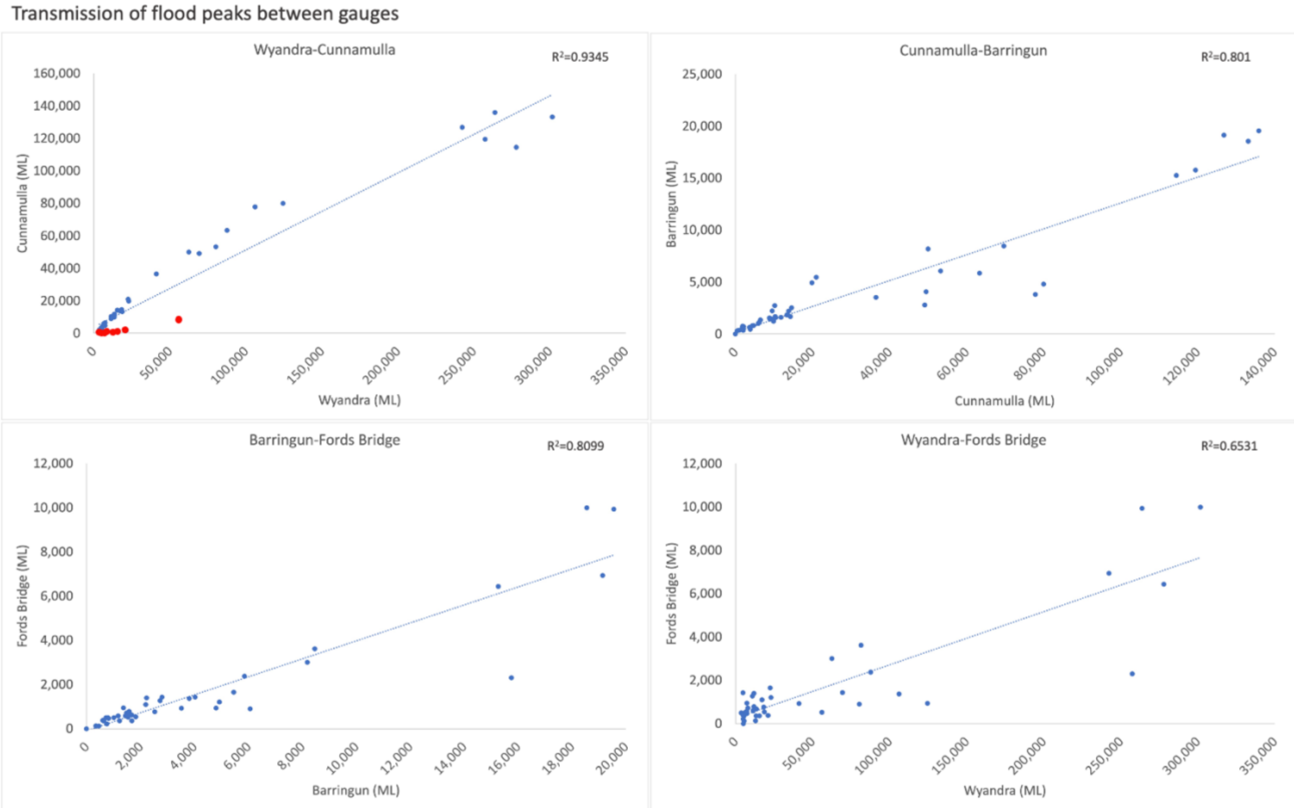

Figure 5 Linear relationship of flood peaks at successive gauges. Red points indicate outliers where the proportion of inter-gauge peak transmission was significantly less than the overall trend.

Downstream flood volume correlation

Figure 6 shows the linear relationship of flood volume (ML) at successive gauges with the strength of the simple linear relationship represented by the r-squared statistic. Analysis showed relatively strong flood-volume relationships for successional gauges with the r-squared values for volume attenuation as follows: Wyandra-Cunnamulla r^2=0.9; Cunnamulla-Barringun r^2=0.8; Barringun-Fords Bridge r^2=0.9; and Wyandra-Fords Bridge r^2=0.6.

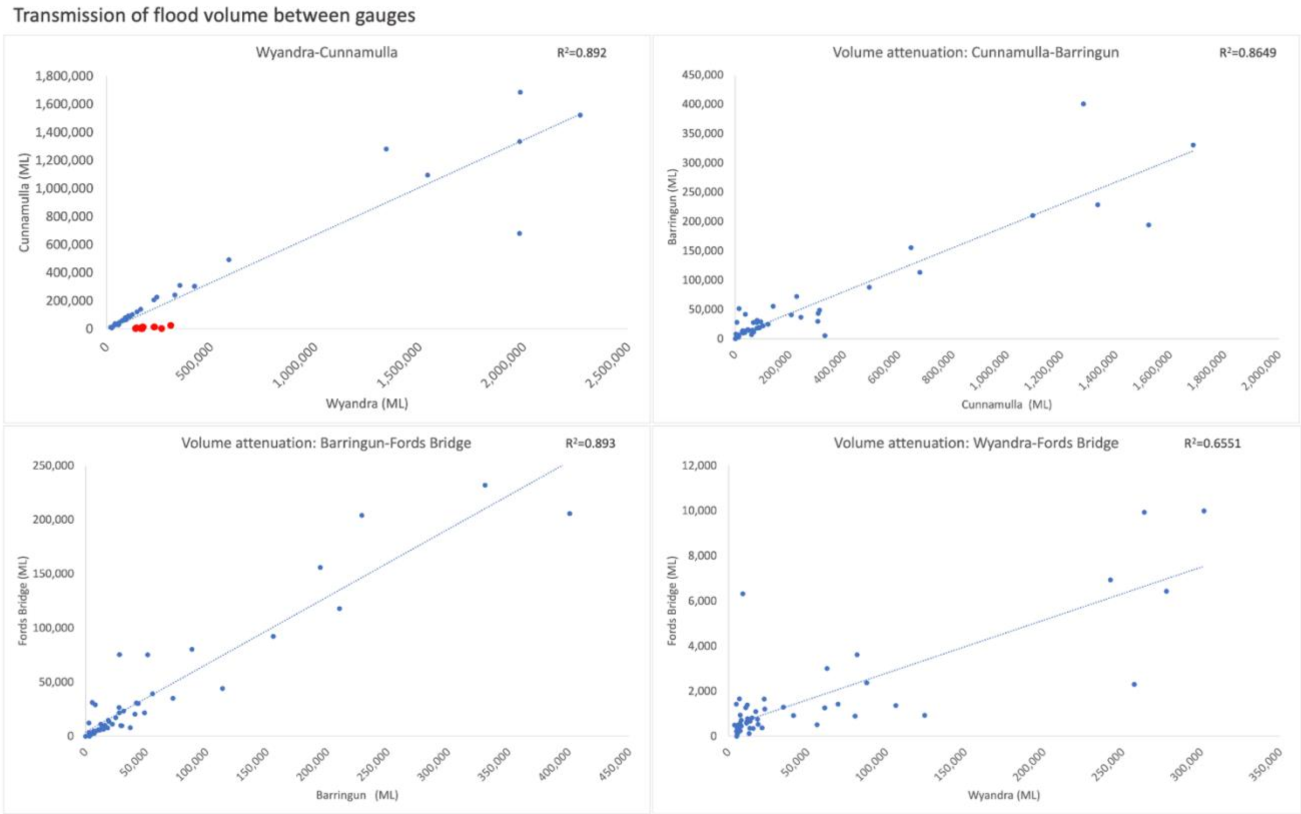

Figure 6 Linear relationship of flood volume at successive gauges. Red points indicate outliers where the proportion of inter-gauge peak transmission was significantly less than the overall trend.

Anomalous Flood Events

Attenuation analysis showed a near-consecutive series of floods that deviated from the general attenuation behaviour of floods in the Warrego channel (Figure 7). These anomalies included eight flood events that occurred between the Wyandra and Cunnamulla gauges between May 1999 and June 2001. This series of anomalies was interrupted by a single event, Event 20, that conformed to the long-term pattern of flood passage and therefore wasn’t considered anomalous.

For these events, substantially less floodwater (peak and volume) passed from Wyandra to Cunnamulla. During these events, between 0 and 10% of the volume of floodwaters that passed the Wyandra gauge made it to the Cunnamulla gauge against on overall transmission rate of over 74%. Four additional events were noted to deviate from the general attenuation behaviour. For these events, the anomalies occurred between Cunnamulla and Barringun where the peak transmission was 5-8% against the long–term average transmission rate of 20%. However, these four additional events were distributed over a period of 16 years, unlike the eight anomalies that occurred in close succession between 1999 and 2001.

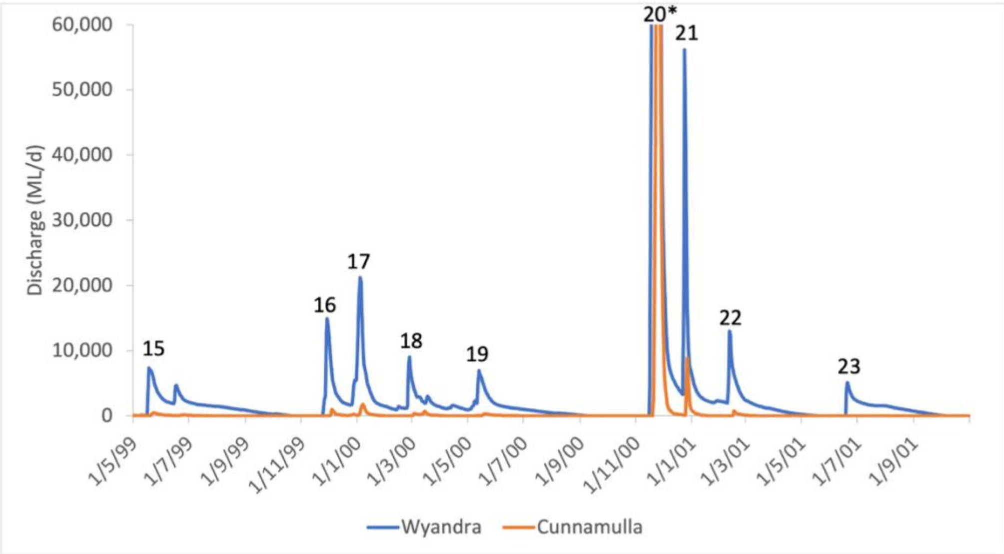

Figure 7 Sequence of anomalous floods between 1999 and 2001. Numbers above blue peaks indicate event number. Event 20* was a 1 in 10-year flood that conformed to the long-term pattern of flood attenuation, so is therefore not considered to be anomalous.

Conclusions

This study revealed that there was generally a predictable and consistent pattern of flood attenuation in the Warrego River during the study period. The passage of flood peaks and volumes from Wyandra to Fords Bridge was predictable for all identified floods with simple linear regression for flood behaviour between successive gauges being 0.77 or greater.

Eight events identified in the period November 1999 and June 2001 between Wyandra and Cunnamulla deviated from this overall predictable pattern. For these events the transmission rate from Wyandra to Cunnamulla decreased to <12% against the general rate of >65%. The causes of the change in flood behaviour during this period are unknown at this stage.

Acknowledgments

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