Received: 19 March 2018 | Revised: 30 July 2018 | Accepted: 6 August 2018

DOI: 10.1002/gdj3.54

DATA PAPER

WILEY Geoscience Data Journal RMetS

Digitization of weekly Murrumbidgee River heights at Hay South Eastern Australia 1873–2017

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Funding information
This article was not funded.

Long-term, high-frequency river height measurements provide a direct method of relating changes in local water availability in a catchment to such phenomena as climate and changes in land use. Here, digitized weekly river height data from the Murrumbidgee River at Hay in south eastern Australia are presented for the first time covering the start of record from November 1873 to June 2017. There are two gauge board locations: (a) The town gauge at the southern edge of the township with data until March 1983, and (b) the Hay Private Irrigation District (PID) gauge on the north eastern outskirts of Hay about 2 km upstream from the Hay town gauge. There is a data overlap of about 13 years for the two locations. The underlying data quality is good taking into account missing values, outliers, continuity between the two gauge locations and measurement practice. The weekly data are available in both annual and seasonal files.

KEYWORDS
annual, digitization, Hay south-eastern Australia, Murrumbidgee River heights, seasonal

Dataset

This dataset contains weekly gauge measurements of the Murrumbidgee River at Hay in south eastern Australia from November 1873 until June 2017. There is one main file that lists all the measurements by year, day, and month in the first column. The observations at the PID gauge are taken on the same day of the week with the time of day usually about 9 a.m. The Town gauge observations were taken on Mondays and/or Thursdays and published the following day. When only one observation was taken per week it varied between Mondays and Thursdays. The time of day was not published for the Town gauge. The next column lists the original measurement in feet or metres. Next is a comments column followed by a column which lists all the Hay town gauge measurements in metres with the calibration adjustment up to June 30, 1920 that is mentioned in the text. The last column lists the Hay PID gauge data. Each of the four seasonal files follow the same structure with the seasons in chronological order.
Identifier: https://doi.org/10.5281/zenodo.1184869
Creator: Milton Speer
Title: Digitized Weekly Murrumbidgee River Heights at Hay South Eastern Australia 1873 to 2017
Publisher: Milton Speer
Publication year: 2018
(Resource type): data
(Version): 1

1 | INTRODUCTION

It is important to consider finer scale or local hydroclimatic patterns in relation to large-scale climate drivers of a region so that more spatially focussed regional assessments of drought and flood variability and hence water availability can be made (Freund *et al.,* 2017). This also applies when considering the effect of catchment development along a river (Kingsford and Thomas, 2001). The Murrumbidgee River catchment in southeast Australia runs close to the southern edge of the state of New South Wales (NSW) and most of the inflow to the Murrumbidgee River occurs on the western part of the Great Dividing Range near where the Burrinjuck and Blowering Dams and a cluster of other smaller dams are located (Figure 1).

The aim of the dataset described in this article is to be able to analyse seasonal streamflow variability by making available digitized weekly Murrumbidgee River heights at Hay from their first recording in November 1873 until

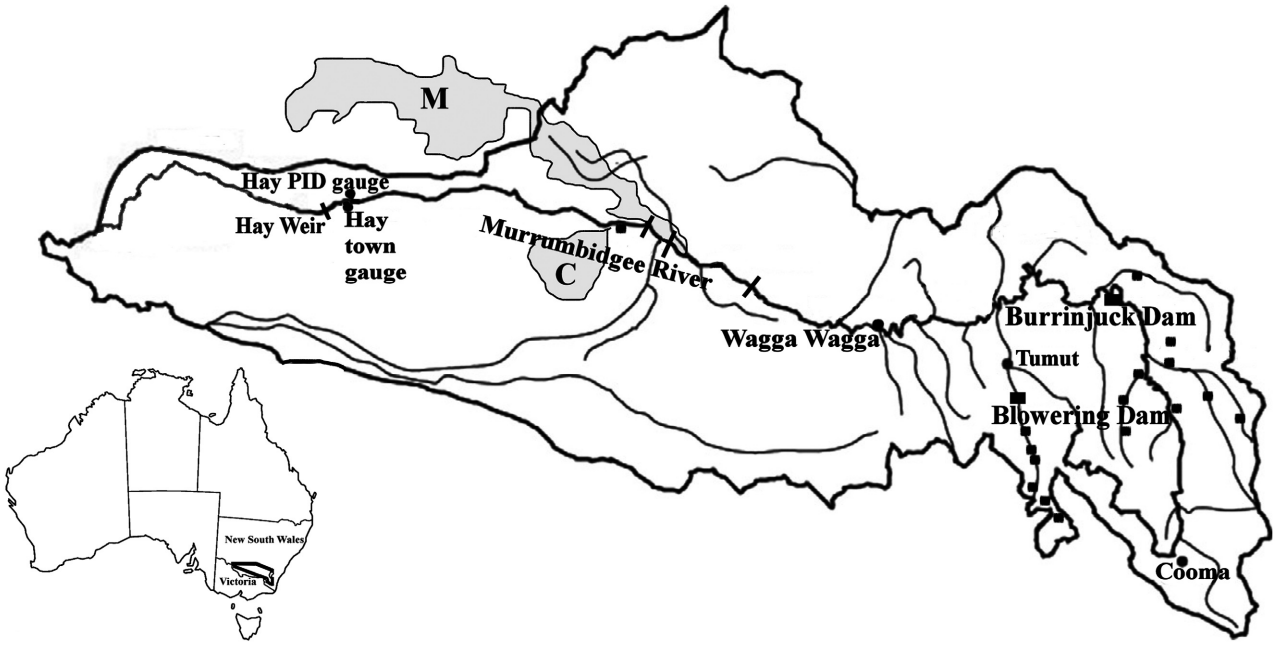

FIGURE 1 Map showing the Murrumbidgee River, tributaries, and catchment including several place names and entities along the catchment. M, Murrumbidgee irrigation area (shaded grey), C, Colleambally irrigation area (shaded grey). Unnamed dams are shown as a square (solid, black). Weirs are shown as a short, solid line (black). The inset identifies the catchment location in south east Australia. The Hay private irrigation district gauge is indicated on the north eastern outskirts of Hay township

2017. Hay is a town located close to the southern border of NSW in south eastern Australia (see inset Figure 1).

2 | DATA ACQUISITION

There are two sources of data. The first is the original Town gauge at Hay on the southern pylon of the old bridge at the southern end of the town (Lat/Long: −34.5166/144.8426, gauge removed after 1983 when bridge was replaced) and the second is the Hay Private Irrigation District (PID) gauge about 2 km further upstream on the north eastern outskirts of the town (Lat/Long: −34.4953/144.8754, see Figure 2 for image of Hay PID gauge). As far as this author is aware, there is no other existing full digital dataset of weekly Murrumbidgee River heights at Hay. The Hay PID weekly gauge data are available in digital format from July 2008. Prior to July 2008 it was recorded manually in books which are now held by the Hay PID.

2.1 | Town gauge

The local Hay newspaper, the *Riverine Grazier,* and the *Sydney Morning Herald,* published the height of the Murrumbidgee River at the Hay town gauge from November 1873 until March 10, 1983. From the late 1870s until 1912 twice weekly measurements were published followed by weekly measurements. The height was recorded as a measurement above or below a reference point termed, "normal summer level." If the height had fallen to below 4 ft above "normal summer level" then only lightly laden vessels were able to dock at the town wharf. Once the level reached 3 ft

FIGURE 2 Hay private irrigation district gauge on the north eastern outskirts of Hay township

above summer level all navigation stopped. From July 1920, "normal summer level" was abandoned by lowering the town gauge 4 ft and a new zero reference level at 4 ft was adopted so the pre-July 1920 heights in this study were adjusted (+4 ft) for consistency in calibration throughout the record https://trove.nla.gov.au/newspaper/page/16295955. The Hay town gauge readings ceased in March 1983 when the gauge was decommissioned.

2.2 | Hay PID gauge

Another gauge about 2 km upstream at the northern end of the town originally owned by the NSW Water Conservation and Irrigation Commission and now owned by the Hay Private Irrigation District (PID) is located where the river is of similar width and slope to where the town gauge was located. Moreover, there is negligible difference in the heights above sea level of the two gauges (Town gauge, 95.7 m; PID gauge 95.9 m). However, the compatibility in the two sites is most strongly related to the data in Table 1. Therefore, the two sets of merged data including the overlapping period, are considered compatible with no need for adjustment. The Hay PID pump irrigates the same area of land of the original Hay town irrigation scheme established in 1895. The two sets of data provide concurrent weekly river height readings from 1969 until March 1983 when the Hay town gauge was decommissioned, and then ongoing weekly measurements of the Hay PID gauge are available from J. Bissett, (personal communication, Hay PID, office@haypid.com.au).

2.3 | General data features

For the Hay town gauge, there are missing data during the 1870s, for much smaller periods later, and July 2013 to June 2014 for the Hay PID gauge. There is a total of 8,580 valid measurements covering the whole period from November 17, 1873 to July 30, 2017 (see Table 1 for basic statistics description), which are also listed separately into files of the four seasons.

There was a transition between September 1982 and March 1983 when the Hay Weir 30 km downstream from Hay came into operation. Backing up of water upstream from the Hay Weir has occurred occasionally since the weir came into operation (J. Bisset, Hay PID, personal communication: 2017). However, this effect is not apparent in the data. When the Hay Weir came into operation from March 1983 there was a rise in the river height which coincided with drought-breaking rains in eastern Australia from March to June 1983 that was associated with the end of the severe El Niño drought of 1982–83. River banks at Hay start overflowing once a height of 6.7 m (22 feet) is reached (see Figure 3).

3 | DATA QUALITY CONTROL

3.1 | Underlying data quality

The underlying data quality appears to be good for both gauges. The reason is that in low streamflow there is little change in the heights while during periods of high streamflow heights consistently rise to peaks and then consistently fall to lower levels.

For both gauges, the heights were read off a gauge board. Originally, it was likely someone from the Hay shire council recorded the town gauge height and sent it to the local newspaper. That would explain why there are consistently missing values for the week between Christmas and New Year and surrounding the week or two over the Easter period during March or April when the council was not staffed, or the newspaper not printed. The Hay PID gauge value would have been initially read by an officer from the NSW Water and Conservation Irrigation Commission and then by the manager of the Hay PID.

From September 1982 to March 10, 1983, the Hay PID gauge was consistently 1.0 to 1.5 m lower than that of the town gauge (Figure 3). A possible reason for this latter mentioned difference may be due to issues associated with the completion of the Hay Weir as it gradually became operational in March 1983 combined with the fact that the lowest readings occurred during the severe El Niño drought in the months leading up to March 1983. The overlap period for the two gauges from 1969 until about 1979 initially

TABLE 1 Basic descriptive statistics for the Hay town gauge, Hay PID gauge, and the measurement overlap period

	Valid *N*	*M*	Median	Min	Max	Variance	*SD*
Town gauge + (PID gauge from March 24, 1983)	8,580	2.65	2.28	0.1	8.99	2.68	1.64
Town gauge	6,870	2.63	2.10	0.1	8.99	2.97	1.72
PID gauge	2,464	2.61	2.48	0.29	9.18	1.88	1.37
Town gauge in overlap period (May 21, 1968–March 17, 1983)	676	2.36	1.92	0.1	8.99	2.63	1.62
PID gauge in overlap period (May 21, 1968–March 17, 1983)	754	2.39	1.92	0.29	9.18	2.66	1.63

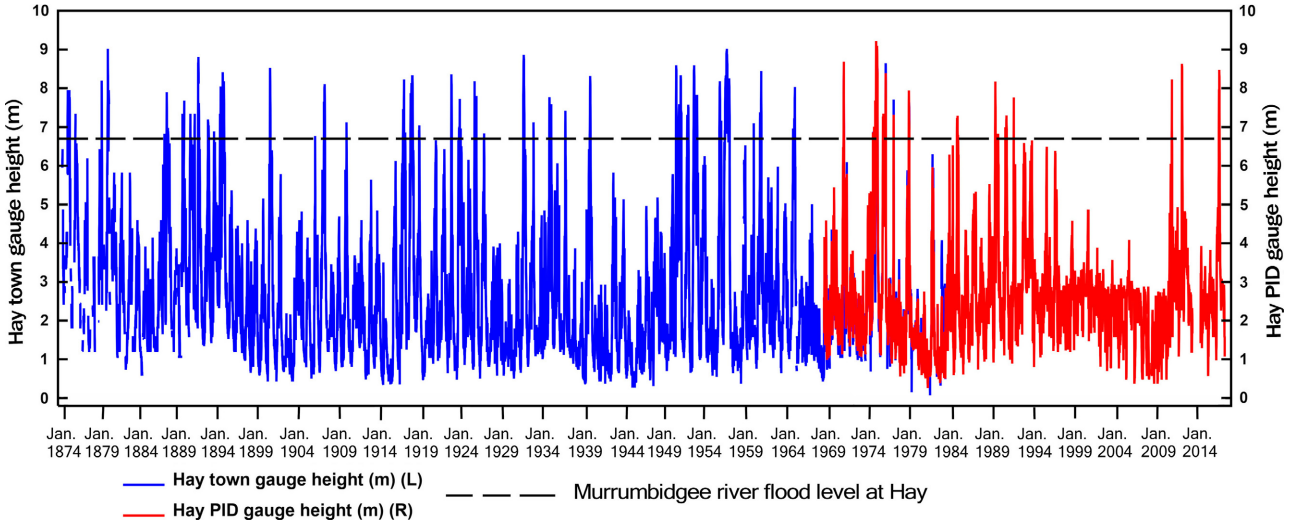

FIGURE 3 Murrumbidgee River heights (m) at the Hay town gauge and Hay PID from November 1873 to June 2017.There are concurrent readings at the two locations from 1969 to March 1983. The first January height every 5 years is indicated. The river flood level is marked (dashed line) at 6.7 m

shows that the Hay PID gauge was consistently 0 to about 0.5 m higher than the town gauge. The two gauges show very similar values between 1979 and September 1982. Basic descriptive statistics of the two gauges and the overlap period between the two gauges is shown in Table 1.

3.2 | Potential changes in measurement practices

It is unlikely that there have been any significant changes in measurement practice apart from the lowering of the town gauge by 4 feet from July 1920 as explained in section 1.1.

3.3 | Changes in site locations

The Hay town gauge board was attached to the southern pylon of the original bridge across the Murrumbidgee River at the southern end of the town. The original bridge was built during 1872/73 and weekly river height recordings were first published starting on November 17, 1873. Therefore, it is very likely that its position remained unchanged until the gauge was decommissioned in March 1983 and eventually removed together with the bridge. The Hay PID gauge site location has also remained unchanged at the pump location which is used for irrigating the PID. A new PID gauge board was fitted on March 02, 1992.

3.4 | Other issues that could affect the data

There is a sequence of seven values for the town gauge from July 03, 1975 to August 14, 1975 which are inconsistent with those values either side, so those seven values have been treated as missing values. There appears to be only one obvious outlier (comment February 10, 1879) of 14 feet which has also been treated as a missing value.

Data drift is only an issue to the extent that the Hay PIDs lowest heights rapidly shifted higher after the Hay weir came into operation at the end of the severe El Niño drought, as explained in section 1.3.

Finally, there appears to be less variability in the heights from about the late 1950s (see Figure 3). While outside the scope of this work, it appears to be related to increasing regulation of streamflow from about 1957 as determined by Ren and Kingsford (2014). The effect of catchment development and climate on river heights at Hay will be considered in future work.

4 | DATASET LOCATION AND FORMAT

In addition to the repository at: https://doi.org/10.5281/zenodo.1184869 the data are freely available from the Climate Change Research Centre, University of New South Wales website at: http://web.science.unsw.edu.au/~mss/

There is a main file and seasonal files in excel format. The main file lists all the heights from November 17, 1873 to June 30, 2017 by day and month including the start of each year at the first January value. Each seasonal file contains a chronological sequence of seasons in the same format as the main file.

5 | DATASET USE AND REUSE

Potential use of these weekly river height data over such a long time period provide a means to consider finer scale or local hydroclimatic patterns in relation to large scale climate

drivers and the effects of catchment development of a region, as mentioned in the Introduction. For example, the weekly data can be used to study the effects on the catchment of changes associated with the seasonal ENSO phenomenon and the decadal phenomenon known as the interdecadal Pacific oscillation (IPO). Limitations to the data use have been covered in section 3 on data quality control.

Currently, the dataset is being used to relate the catchment hydroclimatology at Hay to historical interdecadal and seasonal climate features while attempting to also account for the effect of catchment development. The data have potential uses for organizations involved in areas of interest such as water availability/usage and climate variability and change with the Murrumbidgee River catchment and with the Murray Darling Basin of south eastern Australia in general (e.g., Murray Darling Basin Authority, NSW and Federal Government, irrigators, and research institutions).

ACKNOWLEDGEMENTS

The research presented in this paper was not funded. I am grateful to James Bissett for making available the historical Hay PID gauge data and to Bruce Wall for bringing it and other local information to my attention.

OPEN PRACTICES

This article has earned an Open Data badge for making publicly available the digitally-shareable data necessary to reproduce the reported results. The data is available at http://doi.org/10.5281/zenodo.1184869. Learn more about the Open Practices badges from the Center for Open Science: https://osf.io/tvyxz/wiki.

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How to cite this article: Speer MS. Digitization of weekly Murrumbidgee River heights at Hay South Eastern Australia 1873–2017. *Geosci Data J*. 2018;5:9–13. https://doi.org/10.1002/gdj3.54