

# JSHESS early online view

This article has been accepted for publication in the *Journal of Southern Hemisphere Earth Systems Science* and undergone full peer review. It has not been through the copy-editing, typesetting and pagination, which may lead to differences between this version and the final version.

**A comparison of weather systems in 1870 and 1956 leading to extreme floods in the Murray Darling  
Basin**

Jeff Callaghan

Retired Bureau of Meteorology Brisbane Queensland Australia. 10 October 2018.

## **ABSTRACT**

This research is the extension of a project studying the impact of Nineteenth Century severe weather events in Australia and their relation to similar events during the Twentieth and Twenty First Century. Two floods with the worst known impacts in the Murray Darling Basin are studied. One of these events which occurred during 1956 is relatively well known and Bureau of Meteorology archives contain good rainfall data covering the period. Additionally, information on the weather systems causing this rainfall can be obtained. Rainfall, flood and weather system data for this event are presented here and compared with a devastating event during 1870. Although archived Australian rainfall data is negligible during 1870 and there is no record of weather systems affecting Australia during that year, a realistic history of the floods and weather systems in the Murray Darling Basin during 1870 is created. This follows an extensive search through newspaper archives contained in the National Library of Australia's web site. Examples are presented showing how the meteorological data in Nineteenth Century newspapers can be used to create weather charts. Six such events in 1870 are demonstrated and three of these had a phenomenal effect on the Murray Darling system. The 1870 floods followed drought type conditions and it is remarkable that it was worse in many ways than the 1956 event which followed flood conditions in the Murray Darling Basin during the previous year.

The events in 1870 caused much loss of life from drowning in the Murray Darling Basin (MDB) in particular from an East Coast Low in April 1870 and two Victorian weather systems in September and October 1870. In 1956 there were also record breaking events especially during March when all-time record monthly rainfall were reported in New South Wales. Overall the greatest impact from flooding across the whole Murray Darling Basin was associated with the 1870 flooding.

Analyses of heavy rainfall areas in the MDB shows a linear trend increase from 1900 to 2018. Analysing the same data using an eight year moving average highlights three peaks around the 5 highest annual rainfall years. The largest peak occurred around 1950 and 1956, the second largest around 1973 and 1974 and the third around 2010. Each of these five years occurred during negative phases of the Interdecadal Pacific Oscillation (IPO) and positive phases of the Southern Oscillation Index (SOI). Studies have shown that the SOI is a climate driver in the MDB along with a persistent blocking high pressure systems south of Australia along longitude 140 degrees east with a low to its north. Two major blocking events with record rainfall and flooding in the MDB occurred

in 1983 and 1990. This was during the period 1977 to 1990 when blocking was conducive to heavy rain in the MDB and was coincident with a positive phase of the IPO thus helping conflict with the IPO/MDB heavy rainfall relationship. Persistent and unexplained middle level westerly winds kept sub-tropical Queensland clear of Tropical Cyclones during the negative phases of the IPO from 1999 to 2009 and during the 1960s influencing low rainfall in the MDB during those periods.

Studies have also shown how weather systems with strong pressure gradients impacting on Southeast Australia have been in decline since the latter part of the 19th Century and in the opinion of the authors of those studies, contributing to persistent drought conditions there. Examination of many events have shown that such intense weather systems don't always produce heavy rainfall and that strong weather systems further east from their study area which are associated with flooding rainfall appeared to have increased during the 20<sup>th</sup> Century.

A South Australian modelling study is described which indicates how the 1870 and 1956 historic floods would ensue today with all the various dams, weirs and storage lakes etc. The MDB wet and dry periods evident in the 8 year moving average may, from studies targeting earlier periods have been more extensive than we have experienced during European history.

## **Introduction**

The topic which concerns many people around the globe today is whether climate change is producing more extreme weather events and to this end we have previously studied the impacts of East Coast Lows (ECLs), Tropical Cyclones (TCs) and related weather systems in Australia (Power and Callaghan 2016, Power and Callaghan 2015, Callaghan and Power 2014, Callaghan and Power 2014a, Callaghan and Power 2010 and Callaghan and Helman 2008). This work is now extended to study extreme flooding in the Murray–Darling basin (MDB). The MDB is a large geographical area in the interior of southeastern Australia and contains two major rivers, the Murray and the Darling (see Figure 1) and drains about one seventh of the Australian land mass. Most of its area (1,061,469 km<sup>2</sup>) is flat. The basin, which is one of the most significant agricultural areas in Australia, generally receives little direct rainfall and the rivers it contains tend to be long and slow-flowing, and most of the time carry a relatively low volume of water. For example in relation to the slow flowing rivers the peak flow travel time along the Darling River from Bourke to Wilcannia is about 20 days and along the

Murray River from Hume Weir (near Albury) to Wentworth is around 27 days and a further two weeks to reach Renmark.

The two largest floods in the MDB since European Settlement appear to be the 1870 and 1956 floods. The 1870 flood was the first officially recorded flood. It then was reported see <http://www.samemory.sa.gov.au/site/page.cfm?u=1378> as peaking at 11 metres (no decimals given) at Morgan in South Australia (SA) where the Murray River turns 90 degrees southward. Morgan is 38km north-northeast of Blanchetown which is 90km north northeast of Murray Bridge. The Sergeant of Police at Blanchetown gave the highest water level occurring on 13 December 1870. It washed away homesteads in the region. From Harrison (1957), except in the SA section of the Murray River where the 1956 flood was higher than previously recorded, the 1870 flood was the highest at most places in the Murray River itself.

Prior to the 1956 flood an earlier flood during late October 1955 peaked at 8.3 metres at Morgan and pre-empted the 1956 flood. From the above SA Government site the 1956 Flood peaked at 12.3 metres at Morgan, breached all levees and was the highest flood recorded there since white settlement. Traditionalists argue that it was only the Locks in the Murray River that made it higher than the 1870 flood. Additionally the 1955 floods ensured a moist catchment in 1956 so that less potent rain bearing systems could produce severe flooding than that would occur on a dry catchment.

Trevor Jacobs, Manager of Production, River Murray Water, presented the following facts about the 1870 and 1956 floods:-

“The peak flood height at Lock 11 at Mildura in Victoria (VIC) during 1956 was 11.43 metres but it was exceeded previously in 1870 by about 0.2 of a metre - it was 11.65 metres in 1870. But 1956 further downstream where the Darling joins in, it was the highest ever recorded. At Wentworth New South Wales (NSW) during 1956, the Murray was measured 9.75 metres and in 1870 it was 10.05 metres. The 1870 readings are thought to be accurate. In 1956 the Darling River flood came down the anabranch downstream of Wentworth and became the largest flood downstream of Wentworth about 30cm higher than in 1870. These floods move slowly along the river, taking three days for the peak to make its way from Mildura to Wentworth, and then nearly two weeks

to reach Renmark in SA. The water went down just as slowly, exposing the muddy flood plain left behind in the waters' wake.”

The aim of this study is to help identify and document the weather systems causing the 1870 floods and to compare them with the systems causing the 1956 floods. Below in Section 2 the data used in this study is examined. Section 3 describes the rating of floods and Section 4 refers to some MDB climate studies. Section 5 describes the 6 major weather systems in 1870. Precursor conditions to the 1870 floods are analysed in Section 6 along with a description of the 1870 weather systems and resultant floods in Section 7. Sections 8 similarly explains the 1956 conditions. The conclusions are presented in Section 9.

Appendices are added with Appendix I showing greater detail of the 1870 and 1956 weather systems and impacts while Appendix II presents occurrences of rainfall reported during other 1870 weather systems. Appendix III details the East Coast Lows (ECLs) affecting Eastern Victoria since the 19<sup>th</sup> Century.

## **Data**

As stated above the main aim of this study is to compare the weather systems causing the 1870 floods with the 1956 events. There is little rainfall data available for 1869 and 1870 and little knowledge of the weather systems involved so it becomes essential to use newspaper archived data from the National Library of Australia.

Following Callaghan and Power 2014 the newspaper archives of the National Library of Australia (<https://trove.nla.gov.au/newspaper/>) were searched to build a picture of the activity of rainfall, flooding and weather systems affecting the MDB during 1870. Daily newspapers contained weather observations and flooding information in the northern, eastern and southern areas of the MDB during 1870 and from April onwards when the Darling River began flowing properly after early rainfall, there were reports from steamers moving up and down the Darling River.

Newspapers carried many accounts of flooding around this period probably due to the huge loss of life in NSW from East Coast Lows (ECLs) producing the May 1851 Bega floods, the June 1852 Gundagai floods, the August 1857 *Dunbah* Storm, the 1963, 1864 and 1867 Tropical Cyclones (TCs) in Queensland (QLD) and the June 1867 ECL Hawkesbury River floods (see Callaghan and Power 2014 and 2014a, Callaghan and Helman 2008). Over this period as a result of these storms there was an even greater loss of life from coastal shipping disasters

so newspapers during 1870 contained daily coastal weather and sea observations which enabled weather systems such as ECLs and TCs to be identified.

In contrast there are widespread available rainfall data and weather charts available for the 1956 events.

### **Rating of Flood Events**

The probability of a particular flood level being equalled or exceeded in any one year period can be expressed as a percentage, the annual exceedance probability or AEP, or as an average recurrence interval, or ARI. As an example take a flood level which can be expected to be equalled or exceeded on average once every 100 years. In this case, the ARI is 100 years and the AEP is 1%. It is important to note that an ARI of, say, 100 years does not mean that the event will only occur once every 100 years. In fact, for each and every year, there is a 1% chance (a 1 in 100 chance) that the event will occur. The use of annual exceedance probability (AEP) to describe the chance of a particular rainfall is generally preferred as it conveys the probability or chance that exists for each year. The alternative, ARI, is a term which is easily misunderstood however it is more widely used and appears to be favoured by the public, so we use it here.

### **Climate Studies affecting the MDB**

From a network of reliable long term rainfall stations the area of rainfall very much above average (decile 10) in the MDB has been increasing over the period 1900 to 2018 with Figure 2 showing the decile 10 linear trend.

Note 2010 was also the wettest year on record for the MDB, however it relieved one of the longest and most severe droughts across the MDB in recorded history. There is a clustering of events in the period 1950 to 1980 in Figure 2 so Figure 3 displays the 8 year moving average and this shows clearly that the two largest peaks in rainfall occurred in the 1945 to 1976 period and a third peak near the 2010 extreme rainfall event.

The 8 year moving average was chosen as the heaviest rainfall areas appeared to be associated with the negative phases of the Interdecadal Pacific Oscillation (IPO) (Power et al 1999 and Henley et al 2017) and longer periods smoothed out the rainfall between the two phases of the IPO. The 1945 to 1976 period was the most extensive negative period in all the IPO data. IPO negative values (from UK Met Office data) and Southern Oscillation positive values (monthly average for each year) for the 5 largest annual rainfall totals in the time series which are also the years with the largest areas of decile 10 rainfall were:-

1950 -1.838    +15.3

1956	-1.475	+10.7
1973	-1.450	+10.6
1974	-1.305	+9.6
2010	-1.238	+9.8

The IPO is a long-term oscillation of sea-surface temperatures in the Pacific Ocean that can last from 20 to 30 years. Its positive and negative phases affect the strength and frequency of El Niño and La Niña. The IPO was mainly positive from 1900 to 1944, then positive from 1977 to 1998 and again from 2014 onwards. It was negative from 1945 to 1976 and 1999 to 2014. The positive phases are dominated by El Niño events while the negative phases are dominated by La Niña events. Therefore the positive phases of the IPO before 1945, from 1977 to 1998 and after 2014 are associated with fewer periods of heavy rain in the MDB and the two negative phases from 1945 to 1976 and 2000 to 2014 are associated with heavier rainfall.

Negative periods of the IPO have been found to be associated with enhanced severe tropical cyclone landfalls along the east coast of Australia (Callaghan and Power 2011) and more frequent major flooding along the sub-tropical east coast of Australia (Power and Callaghan 2015). We show below that land-falling tropical cyclones and sub-tropical east coast flooding and led to increased rainfall in the MDB in 1870 and 1956. Risbey et al 2009 showed that the SOI was a strong Climate Driver in the MJB along with situations where a blocking high forms around 140 degrees east and a cut off low forms equator ward of the high. An example of this occurred from 19-20 April 1990 when a high near 140 degree east had a low form to its north near Charleville and move down towards Nyngan and then on 21 April 1990 moved through Central NSW to Gippsland causing unprecedented major flooding at Charleville, Nyngan and Gippsland and caused 7 deaths. There was a similar event in March 1983 where a low tracked from the Kimberley down to Victoria breaking the 1982/1983 drought. These blocking events were aligned with the positive IPO period and Risbey et al 2009 showed blocking at 140 degrees east to be more conducive to rainfall across the MDB from 1997 to 2005 than for the earlier period 1948 to 1976. This is opposite to the rainfall which would be expected from the IPO. This kept the MDB rainfall higher than expected during the 1977 to 1998 positive IPO period. The drought from the start of the next negative period in 1999 to 2009 was coincident with no TCs making land fall along the east coast of Australia south of Mackay between 1999 and 2009. During this period persistent and unexplained middle level westerly winds extended northwards into the Coral Sea steering TCs away from Australia or weakening those moving

towards the coast. A similar occurrence occurred during the 1960s when low rainfall also resulted in the MDB during a negative IPO period (see Figure 3). This persistent middle level westerly flow generally extended into adjacent overland areas and from Callaghan and Power 2016 such flow is not associated with heavy rainfall which also restricted river flow into the MDB.

Alexander et al 2009 and 2011 indicated that intense weather systems extending from the Southern Ocean into the MDB have been in decline through the 20<sup>th</sup> Century and thus reducing rainfall in Southern Australia. The eastern most data points in her 2011 paper which describes a decline in storminess in Southeast Australia are Goondiwindi, Deniliquin and Hobart. Whetton 1990 showed rainfall in eastern Victoria, which is where the heaviest rainfall occurs, to be associated with low pressure systems east of these data points in the Tasman Sea. There is a possible increase in the occurrence of ECLs in Victoria and in related systems along the east coast of New South Wales and Southern Queensland on a scale larger than the change in blocking activity described above. This warrants further investigation which is planned.

In a study we are carrying out on heavy flood rain systems occurring in Victoria 388 systems were identified between 1849 and 2017. In this study we took advantage of a Victorian Government list of major floods from the nineteenth century through to 2007 available on the web:-

[http://www.floodvictoria.vic.gov.au/centric/learn\\_about\\_flooding/flood\\_history/pre\\_1900\\_floods.jsp](http://www.floodvictoria.vic.gov.au/centric/learn_about_flooding/flood_history/pre_1900_floods.jsp)

Major floods since then are obtained from Bureau of Meteorology data. We added other events with significant impact from heavy rain to these in a similar fashion and using similar data to those documented in Callaghan and Power 2014. The 388 events have been reduced to 292 high impact events and 121 of these were associated with ECLs (affecting mainly eastern Victoria and southeast New South Wales). These 121 ECL events are listed in Appendix III. The ECLs have much of their intense pressure gradient east of the eastern most data points of Goondiwindi, Deniliquin and Hobart in the triangular system employed by Alexander et al 2011 which would affect the tendencies they documented. There has been a trend for ECLs affecting Victoria to increase during the 20<sup>th</sup> Century with 36 events over the 50 year period 1900-1949 (0.72 per year) and 69 events over the 68 years from period 1950-2016 (just over 1 per year). The Victorian 8 year moving average decile 10 rainfall (not shown) shows the three largest peaks occurred in the 1950s, 1970s, and in the 2010-2016 period consistent with this increase.

Therefore the occurrence of an increased number of ECLs would be consistent with decreased storminess using their triangular system. As ECLs overall have their rainfall concentrated in Eastern Victoria and New South Wales the contribution to decreased storminess in Western Victoria from ECLs would result in decreased rainfall in Western Victoria and Western New South Wales. It is notable that these latter regions were where the triangular system had a strong relationship with rainfall in Alexander et al 2011. From Power and Callaghan (2016) there has been an increase in major flooding over a similar period in coastal areas east of the MDB and the weather systems involved were mostly ECLs and similar tropical and sub-tropical lows. This differs from Speer (2008) whose study was for Coastal NSW heavy rainfall whereas the former study was for major flooding including Southeast Queensland and extending an extra 7 years to 2013 thereby including a later active negative phase of the IPO.

Many of these 388 weather rain bearing systems described above did not have the intense pressure gradients like those described in Alexander et al 2011 and none of those 388 were associated with the shipwrecks in Alexander et al 2009 Table 2. Reasons for this include that the weather systems move too quickly and rainfall spends little time at any one location and these airstreams associated with these systems are often too dry to generate heavy precipitation. Nevertheless some of the most violent storms have produced extreme flooding for example event 41 in Appendix III on 1 December 1934 caused the worst flooding ever experienced around Melbourne and 20 people perished overland and 17 at sea. Reasons for the extreme rainfall were probably due to a tropical north to northeast airflow ahead of an intensifying low which became slow moving in eastern Bass Strait.

We frequently observe severe windstorms through southern Victoria which don't produce exceptional rainfall and there have been 14 such events since June 2014. Two of these events are described below along with the infamous 1998 Yacht race storm:-

During 26-27 December 1998 a deep low moved at 30km/h just seawards of the Gippsland Coast while rapidly intensifying. On the 27th gales and severe gusts occurred in Gippsland. Tree and building damage was reported in the Rosedale to Orbost area. Severe gusts were experienced at Wilsons Promontory 171km/h, East Sale 152 km/h and Bairnsdale 107 km/h. Storm to hurricane force winds occurred in Bass Strait (Mills 2001) and 6 yachtsmen were killed in the Sydney to Hobart Yacht Race. Unprecedented wave heights developed in eastern

Bass Strait due to the rapid forward speed of the low causing fetch enhancement (Dysthe and Harbitz 1987). A world record wave height was measured from a radio altimeter during an unbelievable rescue mission by a helicopter pilot (Joubert 2005). The top Victorian 24hour rainfall to 2200UTC 26 December 1998 was a modest 69.8mm at Coranderrk Badger Weir (360metres elevation).

During 9-10 October 2016 a front moving at 37km/h passed through Melbourne. The Victorian Emergency Services received more than 5220 calls for assistance. Twenty four rainfall totals around Melbourne and Gippsland were 5 to 10mm.

A deep low 985hPa, 24 June 2014 moved into waters just south of Melbourne at 47km/h. severe wind gusts downed trees, roof damage and collapsed walls with 2 deaths. Flooding in beachside suburbs and the Yarra River caused significant disruption to power and transport as well as widespread coastal erosion. The flood peak in the Yarra River (1.75 m) was notable because it was not associated with heavy rain. Victorian State Emergency Service had 3,500 call outs. The heaviest rainfall in the Yarra catchment in the 24hours to 2300UTC 24 June 2014 was 32.2mm around Melbourne and 52.4 in the hills at Warburton.

Ho et al 2015 Presented MDB rainfall reconstructions based on a novel method using paleoclimate rainfall proxies in the Australasian region spanning from 749 B.C.E. to 1980 C.E. This study shows that prior to the twentieth century, both dry and wet epochs have persisted for longer periods than observed in the instrumental record—with the probability of both dry and wet periods exceeding a decade at least 10 times more likely prior to 1883 than suggested by the instrumental records. Timbal et al 2013 explore the possibility of using those nineteenth-century observations that do exist to construct an estimate of rainfall across the southeastern part of Australia (SEA). This is based on 11 locations comprising either single observing sites or composites of nearby observing sites with long continuous records. This determined a high peak in rainfall during the 1870s comparable to similar wet decadal peaks in the 1950s and 1970s.

### **Schematic mean sea level analyses of the most potent rain producing systems during 1870**

These analyses are created from the observations in the various newspapers which contain pressure data not corrected to mean sea level and in most cases no indication of the elevation of the observation sites even in the

major cities. The contours drawn are only indicative of the isobars. Wind speeds are inferred from the subjective descriptions of the wind observations e.g. light, moderate, fresh, strong, and gale force etc.

As an example of the available weather observations below is a link below to some of the weather observations contained in the Sydney Morning Herald of 27 April 1870. The Melbourne Age and Argus, Brisbane Courier Mail and Adelaide newspapers were also sourced for weather observations.

<https://trove.nla.gov.au/newspaper/article/28420115?browse=ndp%3Abrowse%2Ftitle%2FS%2Ftitle%2F35%2F1870%2F04%2F27%2Fpage%2F1459994%2Farticle%2F28420115>

The analyses were hand drawn (using nearly 50 years of experience) with the only pressure data coming from Brisbane, Sydney, Melbourne and Adelaide so they are necessarily schematic analyses. To a trained eye the wind observations and rain alone reveal the location of the low pressure systems. These analyses were compared with mean sea level pressure analyses with those from the 20th Century Reanalysis ([https://www.esrl.noaa.gov/psd/data/20thC\\_Rean/](https://www.esrl.noaa.gov/psd/data/20thC_Rean/)). These reanalyses ensemble means assimilate only surface observations of synoptic pressure, monthly sea surface temperature and sea ice distribution. It was found that these analyses cannot resolve mesoscale low pressure systems. Two analyses are shown below in Figures 4 and 5 for 0000UTC 26 April 1870 and the second at 0000UTC 8 September 1870.

They both provided some information regarding the synoptic environments of the two systems in the first case the storm was located in an easterly wind regime however only a broad trough in the easterlies was present compared with the ECL actually analysed in Figure 8 lower left frame below. Likewise the 8 September 1870 was located in a westerly wind regime with only a trough system present while Figure 10 lower frame shows the corresponding analyses with an intense low near Melbourne. All the other cases were similar with broad trough features in the reanalyses rather than intense mesoscale lows. If there was some way to incorporate some of the wind observations available from the newspapers into the model obviously the reanalyses will markedly improve.

#### **4-10 March 1870**

A tropical cyclone crossed the coast near Maryborough in Queensland and then became slow moving overland north of Brisbane. Prior to the analyses in Figure 2 the cyclone had been hovering off the Queensland Coast and

with the tropical moisture it brought into New South Wales rain extended across that state. The top two frames of Figure 6 show the cyclone just south of Maryborough (left frame Figure 6) on 2300UTC 4 March 1870 (9am local time 5th) with rain and thunderstorms and thunderstorms extending south to the Sydney area. In the right frame for 2300UTC 5 March 1870 (9am local time 6th) being a Sunday only observations were available from Queensland and these indicate that the cyclone had moved back out to sea northeast of Maryborough. Over the period 7 to 8 March 1870 (centre frames Figure 6) the cyclone moved southwards to be north northeast of Brisbane with rain initially confined to areas north from Tamworth. However as a low developed west of Canberra the rain extended southwards to affect areas in NSW further south. In the two lower frames of Figure 6 the low and the cyclone interacted to form a discrete low off the NSW South Coast. Rainfall initially extended throughout the NSW observational network (into the Riverina) before contracting east by 2300UTC 9 March 1870. There was very heavy rain throughout the New England Tablelands for example Boggabri just to the west of the Tablelands recorded 53.0mm on 2 March and 93.3mm from 6 to 10 March. The east coastal effects of this storm are described in Callaghan and Power 2014a (CP14a).

#### **17-21 March 1870.**

An East Coast Low developed on the North Coast NSW and moved south to Sydney. On 17 and 18 March a low was developing northeast of Brisbane (top frames figure 7) with rain heavy in places along the coast extending into the Northern Basin of the MDB. The low then intensified and moved to the east of Wollongong (lower frames Figure 7) with the heavy rain contracting south into the Murray and Murrumbidgee watersheds.

The east coastal effects are described in CP14a.

#### **Impacts March 1870**

As a result of these two March events there was major flooding on the Darling Downs QLD and in the Namoi River NSW. There were two fatalities.

#### **21-27 April 1870.**

An intense East Coast low developed near Ulladulla over the 25 and 26 April 1870. An active trough lay through NSW (Dashed lines define troughs in the top frames Figure 8) from 21 to 22 April 1870 and there were extensive rain areas from observations in the NSW observational network which indicated rainfall into both the Northern and Southern Sections of the MDB. From 23-25 April 1870 a complex low formed (middle frames Figure 8) maintaining the extensive rainfall. Over the 26-27 April 1870 the East Coast Low formed (lower

frames) with the heavy rainfall focussed on the Riverina districts and the gradually contracting towards the coast.

The east coastal effects are described in CP14a.

### **Impacts 21-27 April 1870**

There were six fatalities in the MDB. The ECL caused disastrous flooding in NSW at Brewarrina (90km ENE of Bourke), Burrowa (Lachlan River), Gundaroo (Lake George), Wheeo and Taralga (Lachlan River), Goolagong, Cowra, Grenfell and Forbes (Lachlan), Wagga Wagga, Yass and Gunning (Murrumbidgee), Gunnedah (Namoi River), Dubbo (Macquarie), Coonamble (Castlereagh River), Cox's Creek area and the Mooki River which flows into the Namoi River. On 22 April 1870 in the Darling River near Bourke two men drowned (from the six mentioned above).

### **10-13 May 1870.**

A low developed near Seal Rocks NSW late on 11 May and moved south to the far NSW South Coast by 13 May. During 10 to 11 May 1870 a complex trough system in Southeast Australia produced widespread rain across NSW (top frames Figure 9) which became more extensive with heavy rain reported and extended into VIC by 12 May (lower frames Figure 9) as a low formed north of Newcastle. An intense low formed during 13 May bringing flood rains to VIC and the Riverina however details of the low were unknown due to multiple telegraph lines downed along the NSW South Coast.

The east coastal effects are described in CP14a.

### **Impacts 1—13 May 1870**

There was one fatality. Disastrous flooding occurred in NSW at Queanbeyan, Bombala, Bibbenluke (Monaro), Gundagai and Wagga Wagga (Murrumbidgee), Dubbo (Macquarie), Gunnedah (Namoi).

### **7-8 September 1870**

Figure 10 (top frames) show that during 6 to 7 September 1870 a moist sub-tropical north to northeasterly airstream flowed into Southeast Australia ahead of a trough System (dashed line) entering VIC where heavy rainfall was developing extending up into the Riverina. An intense low developed over Melbourne (lower frame Figure 10) and the heavy rain became more widespread. As the 986hPa low developed just south of Melbourne

at 9am (local time) 8 September 1870 barometers were down to 994.7hPa at Melbourne, Cape Schanck 988.1hPa and Cape Otway 991.0hPa.

### **Impacts 7-8 September 1870**

There were 18 fatalities. All-time record floods in the Murray River (see Appendix I)

### **1870 October 24-30**

A complex trough system (trough lines depicted by dashed lines) formed over Southeast Australia (Figure 11) and produced widespread rain over NSW and northern VIC on 24 October 1870 becoming heavy over VIC on 25 October 1870. By 27 October 1870 (Figure 12 top frame) a ridge built along the east coast with a trough over western NSW which brought a strong sub-tropical northeast air stream with heavy rain into areas closer to the trough. By 28 October 1870 (Figure 12 centre frame) the trough moved east contracting rain mostly into Northern VIC and eastern NSW. Then on 29 October 1870 (Figure 12 lower frame) the trough interacted with a new trough extending northwards from Bass Strait to produce widespread heavy rain over the Riverina and VIC.

### **Impacts 1870 October 24-30**

There was widespread major flooding in Northern and Western Victoria with 20 fatalities (see Appendix I);

### **Precursor Rainfall to the 1870 Floods.**

From available data (see below) the 1870 flood followed a dry year. At the beginning of 1870 in the Warrego River country in the northern MDB there were reports of very dry conditions and being devoid of grass. Mounted Police Sergeant J.R. Ewens officer in charge of the Blanchetown SA police station, wrote in his diary that the 1870 flood began as early as April 1870 when the river was rising and steamers were moving again down the Darling with wool with the implication that the river was not flowing well prior to April 1870.

There is no record of any sustained major flooding in the MDB in 1869. Below are reports from an extensive search in the Newspaper archives of the National Library of Australia showing the few such events that threatened flooding in the MDB during 1869:-

- 10 April 1869 Report of 2 days of rain around Bourke and at Dubbo (NSW) where there was some street flooding reported. At Leyburn (QLD on the Condamine River) floods swamped the water-course known as

Canal Creek in less than two hours; and much damage was done. At Goondiwindi (QLD on the Macintyre River) the mailman from Mungindi (NSW) reported that the Barwon River had flooded.

- On 21 April 1869 at Goondiwindi the creeks flooded and mails were delayed.
- A Severe ECL 8-9 May 1869 produced major flooding in the Hawkesbury and Nepean Rivers near Sydney NSW. In the MDB there was heavy rain at Queanbeyan and Cooma in NSW but no flooding reports.
- A report was received on 1 July 1869 from the Culgoa River, St George (Qld) and Tamworth (NSW) of beneficial flooding following months of dry weather.
- On 1869 October 16-17 A front with tropical inflow to the east passed through VIC where there was heavy rain producing major flooding at Clunes on the Loddon River. Also there was heavy rain in NSW at Wentworth and Urana.

### **The 1870 remaining weather systems and resultant floods.**

Details of flooding and the weather during 1870 are provided in Appendix I and below is a summary of this information. This summary notes the additional weather systems involved for each month followed by a brief mention of the impacts.

#### **Overview.**

The Darling River flood peaked at Bourke on 30 May 1870 and at Wilcannia around 20 August 1870. Floods initially peaked at Wentworth on 11 August 1870 and then a second flood arrived (probably from the Murray) on 28 September 1870 and the river kept rising until the end of November 1870. In South Australia the flood arrived on 30 September 1870 with the peak around 13 December 1870. Full details can be found in Appendix II.

There were other lesser weather systems which are listed below and these served to add water to the river systems in the MDB enhancing subsequent flood rains.

#### **January 1870.**

- Two weather systems affected the MDB in January one produced a flood in the Warrego River.

- There were no other floods but rainfall occurred throughout both Northern and Southern Basins of the MDB.

### **February 1870.**

There was no significant rainfall during February 1870.

### **April 1870.**

- A rainband during 2-5 April 1870 caused flooding at Cooma.

### **June 1870.**

- There were three rainbands which crossed NSW during June and were probably associated with upper troughs. The influence of upper troughs in generating heavy rainfall in Southeast Australia is discussed in Callaghan and Power (2016).
- Major floods in NSW resulted at Cannonbar (Macquarie River), Adelong Creek (near Tumut), another at Wagga Wagga, Dubbo (2nd highest on record), Tumut and the whole country around Wilcannia was flooded.

### **July 1870.**

- A weak ECL occurred during 10-16 June 1870.
- Over 21-22 June 1870 a rainband with an upper trough crossed eastern Australia with moderate flooding at Roma and Saint George in the Southeast Interior of Qld.

### **August 1870.**

- There were a series of unstable troughs producing Thunderstorms.
- Flooding in the Condamine and Macintyre Rivers in the Darling Downs (QLD) resulted. Inglewood reported one of the greatest floods in the Macintyre for many years.

### **September 1870.**

- A rainband over 17-20 September 1870 crossed NSW and Kiandra reported 85.9mm in 24hours.
- On 26 September 1870 at Wentworth one boy was drowned as the population were about to abandon the town.

### **October 1870.**

- Over 4-5 October 1870 an area of thunderstorms affected the Darling River District.
- A rainband crossed NSW during 24-25 October 1870.
- The Darling River storms generated 50mm of rain over two days and appeared to be widespread.
- With the NSW rainband flooding occurred at Adelong (near Tumut) and at Young and there was one fatality.

### **Snow.**

On 5 October 1870 there were report from the east indicating there was more snow in the Australian Alps than had ever before been known which had serious consequences for snow melt floods.

### **November 1870.**

- A rainband crossed NSW over 11-14 November 1870.
- An ECL occurred during 16-19 November 1870.
- In NSW a fourth flood occurred at Moulamein and there was one at Yass.
- There was a flood in the Condamine at Warwick (QLD).

### **December 1870.**

There were no major weather systems.

### **MDB rainfall during 1956 and precursor rainfall to the 1956 Floods.**

The period from the 1 January 1956 to 30 June 1956 in the MDB the rainfall (Figure 13) was very much above average to highest on record.

Leading up to the 1956 record MDB rainfall the period from the 1 January 1955 to 31 December 1955 in the MDB (Figure 14) the rainfall was mostly above average to very much above average.

During late October 1955 for instance the Murray River flood peaked 8.3metres at Morgan in South Australia and pre-empted the 1956 flood.

The second half of 1956 the rainfall in the MDB was closer to average (Figure 15).

This study concentrates on the rainfall from January to July 1956 as during August the heavy rain ceased with mostly below average rainfall in the Basin.

Full details of flooding and the weather during 1956 is provided in Appendix I and below is a summary of this information.

### **Overview**

Over January and February 1956 four weather systems affected the MDB and these produced floods in Southern QLD, northeast sections of the MDB and in Northern VIC. During March 1956 seven weather systems produced all-time record rainfall and widespread major flooding over much of the MDB. During April and May seven weather systems caused flooding in smaller areas of QLD, NSW and VIC. Six weather systems during June and July 1956 produced major flooding and some record flooding in the MDB.

The record March rainfall caused the Darling River to flood at Bourke by 22 March 1956, reaching Wilcannia by 26 April 1956 and by 28 May 1956 was 22.5km wide approaching Wentworth and the Murray River. The combined Murray and Darling Rivers flooded Renmark early June and by 1 July 1956 the SA section of the Murray was 3.2km wide. A new flood pulse came down the Murray River to Wentworth on 17 July 1956 while the Darling was on the rise again at Bourke reaching 13.61metres on 31 July 1956. The floods peaked at Wentworth on 15 August reaching 9.78metres, Renmark 23 August 10.2metres and a little later at Morgan 12.3metres. The new peak in the Darling reached Menindee on 2 September 1956 (from Harrison 1957) when the gauge there read 10.06metres. The Darling River peak reached Burtundy (50km NNE of Wentworth) on 12 September 1956 as the Murray was dropping.

### **January 1956.**

MDB January 1956 rainfall varied from average to very much above average with a record rainfall area in the Darling Downs.

- Over 18-20 January 1956 an active monsoon trough with tropical northeasterly flow into a front took place over Southeast Australia.
- There were floods in VIC at Shepparton and Lima South.

- During 20-23 January 1956 a Tropical Low near Mackay had a trough to the south which dominated the rainfall.

- There was a record flood in Macintyre Brook at Inglewood and unprecedented floods were experienced in the Condamine and Macintyre rivers.

### **February 1956.**

MDB February rainfall 1956 Rainfall in the Northern Basin of the MDB was very much above average with pockets of record rain in the Warrego, in the Namoi and in the eastern Darling Downs.

- An inland trough developed over 5- 8 February 1956 and formed the ECL of 9-11 February 1956.

- The second major system was a rapid intensifying tropical low near Tweed Heads NSW over 17-19 February 1956.

- In QLD record floods occurred in the Macintyre and Condamine Rivers. There were also floods in the Balonne and Barwon Rivers. In NSW major flooding occurred in the Macintyre, Namoi and Gwydir Rivers.

### **March 1956.**

Record Rainfall March 1956 occurred. The NSW state wide historical March average rainfall is 48.97 mm. The March record is 155.31 mm which occurred during March 1956.

- A low developed 24 February -1 March 1956 near Lord Howe Island and moved towards the coast under the influence of the very large circulation of TC Agnes.

- A trough crossed NSW 2-3 March 1956 with a tropical moisture feed in from TC Agnes.

- A trough near Adelaide 5-6 March 1956 developed into a low in the Eastern Great Australian Bight with tropical flow into Victoria from TC Agnes (approaching Townsville). Agnes (named by the media) had a very large circulation which enabled it to bring high tropical moisture into Southeast Australia (Callaghan and Smith 1998).

- TC Agnes hit Townsville on the 6 March 1956 and heavy rainfall affected southern states as the moisture from Agnes penetrated there and interacted a major front over 6-9 March 1956. Agnes then moved down to the Western Qld/NSW border by 12 March 1956 and brought heavy rain into the MDB.

- Northerly to northeasterly tropical inflow over 13-14 March 1956 flowed into a trough over Southwest Qld (ex TC Agnes) and across Southern NSW and Western VIC. This interaction developed into a complex low over Tasmania.

- Over 19-20 March 1956 a large high moved into the Tasman Sea with tropical northeast winds and a strong pressure gradient across Southern Qld and NSW.

- By 0000UTC 29 March 1956 an active monsoon trough with an intense low below 990hPa developing in Southwest QLD at 0000UTC 30 March 1956 ahead of a 500hPa low. This then merged with a strong surface front through Southwest QLD and Western NSW/VIC by 0000UTC 1 April 1956.

- The following impacts occurred from the above March 1956 weather systems: Major flood at Canberra; Record rain fell over the Darling River District and Northern Victoria; Major floods occurred at Cooma and the second highest flood at Dubbo (with 1870); Major floods in the Lachlan, Macquarie and Bogan Rivers affecting Forbes, Warren, Wellington, Cowra, Canowindra, Narromine and Nyngan; Major floods at Goodooga (30km SW of Hebel) and Brewarrina District (90km ENE of Bourke); Extreme rainfall at the end of March led to record QLD floods in early April in the Warrego River at Charleville, Wyandra and Cunnamulla and floods in the Maranoa River.

#### **April 1956.**

During April 1956 rainfall in the MDB was mostly average to very much above average with highest on record around NE Highlands of VIC.

- Over 14 -16 April 1956 982hPa a low was located west of Tasmania and from 16-19 April 1956 the low moved slowly to the south of Tasmania.

- During 25-26 April 1956 a 1007hPa low over Central NSW moved east to become a 1000hPa low east of Coffs Harbour.

- Major Floods in occurred in VIC rivers, Avoca, Upper Murray, Ovens and Mitta Mitta.

#### **May 1956.**

During May 1956 rainfall in the MDB was mostly above to very much above average with highest on record in Western Victoria and nearby NSW. Also small pockets of highest on record rainfall occurred in SW and NE NSW.

- A 1000hPa low developed in Gippsland May 1-3 1956 and moved east. Ahead of this development a trough lay from Central QLD to Western VIC with a northeasterly airstream feeding into it.
- An inland low 11–13 May 1956 intensified off the NSW South Coast and moved away.
- Over 10-11 May 1956 a 1003hPa low developed over northwest NSW.
- During 13-14 May 1956 a 985hPa low S of WA moved into The Great Australian Bight and deepened to 975hPa on 15 May 1956 and then weakened to 995hPa on 16 May 1956.
- Major floods occurred in NSW at Gunnedah and Wagga Wagga, in Victoria at Rochester on the Campaspe River with an ARI >100years at Avoca (one fatality), at Shepparton and Maryborough. In Queensland there was sustained flooding in the lower Balonne and Moonie rivers.

### **June 1956.**

- During June 1956 rainfall in the MDB there was mostly above to very much above average with highest on record around parts of the ACT and nearby.
- A 1005hPa low near Lord Howe Island 9 June 1956 rapidly intensified to below 994hPa and moved near the coast east of Wollongong in 24 hours.
- An ECL developed over 24–26 June 1956 with eight fatalities at sea. As it moved from north of Fraser Island to the Gold Coast it then amalgamated with an inland low to form an intense depression off the South Coast of NSW on 26 June 1956.
- Murrumbidgee floods occurred at Gundagai, Wagga Wagga, Narrandera and Darlington Point. Major flood occurred in the Murray River at Albury and in the Molonglo River. Major floods were reported at Coonamble, Dubbo, Forbes and Narromine in the Lachlan River and at Goondiwindi (Qld) on the Macintyre River.

### **July 1956.**

July 1956 rainfall in the MDB was average grading to very much above average to highest on record west of a line from Tambo (SW Qld) to the ACT.

- Over July 6-8 1956 a 1010hPa low near Adelaide with tropical inflow to east, moved to become a 1000hPa low southeast of Tasmania.
- A low deepened and moved from southwest NSW to east of Sydney 11-12 July 1956.
- 16-17 July 1956 a 1000hPa low south of Ceduna moved to near Mt Gambier with heavy rain through Riverina.
- During 24-26 July 1956 a 995hPa Low complex south of Adelaide and Melbourne moved into the southwest Tasman Sea with a series of fronts.
- Record flood levels reported in the Warrego, Bulloo and Paroo Rivers in QLD. Major flood also were reported at Echuca, Mildura, Shepparton, Albury Wodonga, Wangaratta, Rochester, Charlton, Rodsborough (near Bendigo) and in NSW at Balranald and Deniliquin and in the NSW Murray towns of Wagga Wagga, Barham and Wakool.

### **Conclusion**

Over much of the MDB the 1870 flood appears to have had a larger impact than the well-known 1956 flood. This was despite it occurring with dry drought like conditions at the beginning of 1870 whereas the 1956 flood followed the 1955 MDB flood. In fact one of the worst and deadliest NSW floods (Bond, H.G. and Wiesner 1955), occurred in February 1955 and affected a large area of the MDB. Three of the events during 1870 were unprecedented. A complex low and trough moved across NSW from 21 April 1870 to form an ECL on 27 April 1870 and deluged much of NSW. Such slow moving systems tend to produce the most destructive floods. Other examples are the record 1867 Hawkesbury River flood around Sydney and the 1893 Brisbane River flood (Callaghan and Power 2014) and more recently the Houston (US) 2017 flood associated with Hurricane Harvey (Callaghan 2018). The low pressure system which impacted on VIC from 6-8 September 1870 was another unprecedented event producing a record flood in the Murray River with an ARI of 150years. This was quickly followed by a devastating low pressure trough which caused much loss of life during October 1870. There were record events also in 1956 and the Month of March 1956 produced record rainfall across NSW. This excludes 1870 which appears to have had extreme March 1870 rainfall from the few available observations. Tropical Cyclone Agnes played a huge role in generating the large March rainfall in 1956 from its own track inland into the MDB and its interaction with other systems passing to its south.

Bureau of Meteorology data indicate that rainfall over the MDB over the last Century showed the peaks in activity all aligned with negative phases of the IPO. Blocking high pressure low pressure couplets located near longitude 140 degrees were also shown to favour heavy rain in the MDB which occurred during the latter positive phase of the IPO conflicting with the IPO trend. Persistent and unexplained middle level westerly winds kept sub-tropical Queensland clear of Tropical Cyclones during the negative phases of the IPO from 1999 to 2009 and during the 1960s influencing low rainfall in the MDB during those periods.

Studies have also shown how weather systems with strong pressure gradients impacting on Southeast Australia have been in decline since the latter part of the 19th Century and in the opinion of the authors of those studies, contributing to persistent drought conditions there. Examination of many events have shown that such intense weather systems don't always produce heavy rainfall and that strong weather systems further east from their study area which are associated with flooding rainfall appeared to have increased during the 20th Century.

From Bloss et al (2015) historical events have been analysed using modelling studies to ascertain how they would impact in SA today given the large number of mitigation effects such as dams etc that have been constructed. In their study modern basin development (such as dams and irrigation) would not have had a large flood mitigation impact on the 1956 flood. This was the largest event in their time series and it was mitigated only slightly to 93% of the without development flow. There was no data for the 1870 flood but it would probably today result in larger mitigation effect than the 1956 flood due to more flood water being diverted to natural and man-made water storages as a result of the dry precursor conditions. Obviously an 1870 type event following a wet year would be a worst case scenario.

## **References**

Alexander L, Power S. 2009. Severe storms inferred from 150 years of sub- daily pressure observations along Victoria's "Shipwreck Coast." Australian Meteorological and Oceanographic Journal 58(December): 129–133.

Alexander, Lisa V., Xiaolan L. Wang, Hui Wan, and Blair Trewin 2011: Significant decline in storminess over southeast Australia since the late 19th century. Australian Meteorological and Oceanographic Journal 61 (2011) 23-30.

Bloss, C, G. Eckert and L Cetin 2015. River Murray flood mitigation planning: Assessment of flood consequences, Department of Environment, Water and Natural Resources December, 2015 *DEWNR Technical report 2015/56. 41pages.*

Bond, H.G. and Wiesner, C.J., 1955. The floods of February 1955 in New South Wales, January 1956, *Australian Meteorological Magazine 1,1-33.*

Brunt, A.T. 1956. The Record Floods In South East Queensland January 1956, *Australian Meteorological Magazine No 15, 12-30.*

Callaghan, J. 2018: A Short Note on the Rapid Intensification of Hurricanes Harvey and Irma. Tropical Cyclone Research and Review. 2018, 7 (3): 164; **doi:** 10.6057/2018TCRR03.02  
<http://tcrr.typhoon.gov.cn/EN/abstract/abstract143.shtml>

Callaghan J and S. B. Power 2016. A vertical wind structure that leads to extreme rainfall and major flooding in southeast Australia, *Journal of Southern Hemisphere Earth Systems Science (2016) 66,380-401.*

Callaghan J and S. B. Power 2014. Major coastal flooding in south-eastern Australia 1860–2012, associated deaths and weather systems *Australian Meteorological and Oceanographic Journal 64,3, 183-213.*

Callaghan J. and S. B. Power 2014a; Major coastal flooding in south-eastern Australia 1860–2012, Supplementary appendix - details on severe weather systems over southeast Australia, 1799-2013.

Callaghan, J. and S. B. Power 2011: Variability and decline in the number of severe tropical 422 cyclones making land-fall over eastern Australia since the late nineteenth century. *Climate Dynamics*, **37**, 647-662, DOI 10.1007/s00382-010-0883-2.

Callaghan J. and Helman P. 2008 Severe Storms on the east coast of Australia 1770-2008, Griffith Centre for Coastal Management, Griffith University Gold Coast Queensland.

Callaghan J. and R. Smith 1998. The relationship between maximum surface wind and central pressure in Tropical cyclones, *Australian Meteorological Magazine* 47, 191-202.

Dysthe, K.B. and Harbitz, A. 1987: Big waves from polar lows. *Tellus* 39A, 500-508.

Joubert Peter N. OAM 2005: "Some remarks on the 1998 Sydney Hobart Race". *Transactions of the Royal Society of Victoria* volume 117 number 2.

Mills, G. A. 2001. Mesoscale cyclogenesis in reversed shear - the 1998 Sydney to Hobart yacht race storm. *Aust., Met., Magazine*. 50, 29-52.

Power S. B. and Callaghan J 2016. The frequency of major flooding in coastal southeast Australia has significantly increased since the late 19th century. *Journal of Southern Hemisphere Earth Systems Science*.

Power S.B. and Callaghan J. 2015. Variability in severe coastal flooding in south-eastern Australia since the mid-19th century, associated storms and death tolls. *Journal of Applied Meteorology and Climatology*. 55 1139-1149.

Power, S., T. Casey, C. Folland, A. Colman, and V. Mehta, Inter-decadal modulation of the impact of ENSO on Australia, *Climate Dynamics*, 15(5), 319–324, 1999.

Harrison B.E. 1957. Report on the Murray River Flood Problem, Murray River Commission, 69 pages.

Henley B.J., G. Meehl, S. B. Power, C. K. Folland. A. D. King, J.N. Brown, D. J. Karoly, F. Delage, A. J.

E. Gallant, M. Freund and R. Neukom 2017. Spatial and Temporal Agreement in Climate Model Simulations of the Interdecadal Pacific Oscillation. *Environmental Research Letters* · January 2017, DOI: 10.1088/1748-9326/aa5cc8.

Ho M, Keim AS, Verdon-Kidd DC. 2015. A paleoclimate rainfall reconstruction in the Murray-Darling Basin (MDB), Australia: 2. Assessing hydroclimatic risk using paleoclimate records of wet and dry epochs. *Water Resources Research* (51): 8380–8396. DOI: 10.1002/2015WR017059.

Risbey J. S., M.J. Pook, P. C. McIntosh, M. C. Wheeler and H.H. Hendon 2009. On the Remote Drivers of Rainfall Variability in Australia. *Monthly Weather Review* 137, 3233-3252.

M. Speer On the late twentieth century decrease in Australian east coast rainfall extremes 2008 *Atmos. Sci. Let.*

Timbal B, Fawcett R. 2013. A Historical Perspective on Southeastern Australian Rainfall since 1865 Using the Instrumental Record. *Journal of Climate* 26(4): 1112–1129. DOI: 10.1175/JCLI-D-12-00082.1.

Whetton .P H. 1990; Relationship between monthly anomalies of Australian sea-surface temperature and Victorian rainfall. *Aust. Met Magazine*, 38, 31-41.

### **List of Illustrations**

Figure 1 Murray Darling Basin Map Courtesy of the Murray Darling Basin Authority.

Figure 2 Linear trend for heavy rainfall percentage area through the Murray Darling Basin 1900-2018.

Figure 3 Eight year moving average trend for heavy rainfall percentage area through the Murray Darling Basin 1900-2018.

Figure 4 Ensemble Mean MSL analysis (Pascals) 0000UTC 26 April 1870

Figure 5 Ensemble Mean MSL analysis (Pascals) 0000UTC 08 September 1870

Figure 6 Wind observations where half barb/barb/flag denotes 2.5ms-1, 5ms-1, 25ms-1 and “O” indicating calms for 2300UTC 4 March 1870 (9am local time 5th) in top left frame, 2300UTC 5 March 1870 (9am local

time 6th) in top right frame, 2300UTC 6 March 1870 (9am local time 7th) in centre left frame, 2300UTC 7 March 1870 (9am local time 8th) in centre right frame, 2300UTC 8 March 1870 (9am local time 9th) in lower left frame and 2300UTC 9 March 1870 (9am local time 10th) in lower right. Red circles indicates rainfall at 2300UTC or 0500UTC at the station.

Figure 7 As in Figure 1 except for 2300UTC 16 March 1870 (9am local time 17th) in top left frame, 2300UTC 17 March 1870 (9am local time 18th) in top right frame, 2300UTC 18 March 1870 (9am local time 19th) in lower left frame and 2300UTC 20 March 1870 (9am local time 21st) in lower right.

Figure 8 As in Figure 1 except for 2300UTC 20 April 1870 (9am local time 21st) in top left frame, 2300UTC 22 April 1870 (9am local time 22nd) in top right frame, 2300UTC 22 April 1870 (9am local time 23nd) in centre left frame, 2300UTC 24 April 1870 (9am local time 25th) in centre right frame, 2300UTC 25 April 1870 (9am local time 26th) in lower left frame and 2300UTC 26 April 1870 (9am local time 27th) in lower right.

Figure 9 As in Figure 1 except for 2300UTC 9 May 1870 (9am local time 10th) in top left frame, 2300UTC 10 May 1870 (9am local time 11th) in top right frame, 2300UTC 11 May 1870 (9am local time 12th) in lower left frame and 2300UTC 12 May 1870 (9am local time 13th) in lower right.

Figure 10 As in Figure 1 except for 2300UTC 5 September 1870 (9am local time 6th) in top left frame, 2300UTC 6 September 1870 (9am local time 7th) in top right frame and 2300UTC 7 September 1870 (9am local time 8th) in lower frame.

Figure 11 As in Figure 1 except for 2300UTC 23 October 1870 (9am local time 24th) in top frame, and 2300UTC 24 October 1870 (9am local time 25th) in lower frame.

Figure 12 As in Figure 1 except for 2300UTC 26 October 1870 (9am local time 27th) in top frame, 2300UTC 27 October 1870 (9am local time 28th) in centre frame and 2300UTC 28 October 1870 (9am local time 29th) in lower frame.

Figure 13 Decile rainfall MDB 1 January 1956 to 30 June 1956.

Figure 14 Decile rainfall MDB 1 January 1955 to 31 December 1955.

Figure 15 Decile rainfall MDB 1 July 1956 to 31 December 1956.

## Appendix I

### Details of Impacts during 1870

Events	Impacts
<p>January 1870 Events (see Appendix II for details)</p> <p>First weather system – rainband with heavy areas with thunderstorms 3-4 January 1870</p> <p>Second weather system – rainband with heavy areas with thunderstorms 26 -27 January 1870.</p>	<ul style="list-style-type: none"> <li>•Torrential rain in the Warrego produced the biggest flood in years. Previously the country was very dry and devoid of grass.</li> <li>•No other known flooding but rainfall served to moisten catchments throughout both Northern and Southern Basins.</li> </ul>
<p>March 1870 events</p> <p>Tropical Cyclone 2-12 March 1870 and East Coast low 12-21 March 1870 (see Appendix II for details) and weather systems are analysed in Section 7.</p>	<p>2 -10 March 1870 see Figure 2 where ex tropical cyclone moved southward down through eastern NSW. East Coast Low 17-21 March 1870 (see Figure 3)</p> <ul style="list-style-type: none"> <li>•There was very heavy rain throughout the New England Tablelands for example Boggabri just to the west of the Tablelands recorded 53.0mm on 2 March and 93.3mm from 6 to 10 March.</li> <li>• Condobolin recorded 36.8mm 8 March.</li> </ul>

	<ul style="list-style-type: none"> <li>• Sat 5 March 1870 - Large flood at Tamworth from downpour in neighbouring hills- water entered the newspaper office. Heavy rain 6 and 7 March 1870. Floods caused much damage at Tamworth.</li> <li>• Sat 11 March 1870 - Narrabri The river and creek were bank high. Many of the people had their furniture packed up.</li> <li>• 14 March 1870 Dalby - Condamine and River and creeks all flooded railway dam burst; roads badly damaged.</li> <li>• 18 March Two fatalities- In floods near Narrabri one man was drowned in the Mehi River and another in the Barwon River.</li> </ul>
2-6 April 1870 Rainband (Details in Appendix II).	<ul style="list-style-type: none"> <li>• Cooma Tue 5 April 1870 A great flood reported it started raining Sunday evening 3 March.</li> </ul>
East Coast Low named the Walter Hood Storm 21-27 April 1870 which claimed many lives and the storm is analysed in Section 7.	<p>Widespread floods from the Walter Reid Storm with rivers flowing out to Bourke and others flowing through the Riverina system.</p> <ul style="list-style-type: none"> <li>• April 1870 Rainfall - Bathurst 32.0mm 22nd; 25.9mm 23rd; 20.3mm 25th; 17.8mm 27th; 143.7mm for the month.</li> <li>• 22 April 1870 Brewarrina (98km east of Bourke) rain began and was heavy nearly all night and continued for 2 days and nights.</li> <li>• 26 April 1870 Burrowa (Lachlan River.) had the worst flood since European settlement Tuesday evening 26 April 1870.</li> <li>• 26 April 1870 Gundaroo (near Lake George on Yass River) Tuesday 26 April raging foaming torrent covered the flats like an ocean. The torrent subsided by evening but all fencing was swept away.</li> <li>• 25 April North of Goulburn -Wheeo Monday 25 April 1870 and Taralga Tuesday 26 April had torrential rain and record floods. At Wheeo enormous logs were lifted and huge trees torn up by the roots.</li> <li>• 26 April 1870 - Yass Flood. At 4pm 26 April the town was one lake of water, dotted here and there with roofs and tree- tops. It was calculated that the floods reached 2.5metres higher than the 1852 flood.</li> </ul>

	<ul style="list-style-type: none"> <li>•26 April 1870 - Gunnedah (Namoi River) – The River started rising Sunday morning and by 12noon Monday 25th it had risen over 15.2 metres with every house in the main street inundated.</li> <li>• 27-28 April 1970- Forbes - The Lachlan River swept houses away while the water flooded right up to the roofs on others and people sheltered on roofs.</li> <li>• April 27 1870 - Gunning (Just east of Yass) record flood 33cms over the bridge.</li> <li>•27 April 1870 -Total flood destruction at Cowra (Lachlan River) and before noon all houses were swept away on the flats. There was one fatality.</li> <li>•27 April 1870 - Dubbo (Macquarie River) there was much damage from the floods with some houses swept away.</li> <li>•28 April 1870 Wagga Wagga - The Murrumbidgee River reached 10.67metres ranked 2nd after the October 1844 flood. There were two fatalities.</li> <li>•29 April 1870 Grenfell (West of Cowra) Western approach to Cowra Bridge washed away and 19 houses washed away. There was 5.79metres of water in Onsby’s public house. One fatality. 30 April 1870 - Coonamble (Castlereagh River) the rain commenced on Thursday night 28 April, then all Friday and part of Saturday 30 April. At 1:30am Sunday the town flooded until Tuesday. It was reported that Coonamble has been nearly destroyed by the floods.</li> <li>•30 April 1870 Goolagong Lachlan River widespread destruction with stores and cattle swept away.</li> <li>• 30 April 1870. Great damage was done on Cox's Creek. Nearly all the dams on Melville Plains and Bando were washed away, and there were heavy losses in stock and the water from the Mooki River (flows into the Namoi) has covered fifteen miles of Breeza Plains.</li> </ul>
<p>East Coast Low 10-13 May 1870 and the storm is analysed in Section 7.</p>	<ul style="list-style-type: none"> <li>•12 May 1870 Queanbeyan - Heavy rain washed a bridge away.</li> <li>•13 May 1879 Bombala highest flood ever known with the new iron bridge washed away.</li> <li>•13 May 1870 Gunnedah - A flood swept over the main Street the worst since 1852.</li> </ul>

	<ul style="list-style-type: none"> <li>•13 May 1870 Bibbenluke in Monaro -A record flood occurred. Fences were washed away and gardens destroyed. One woman drowned.</li> <li>•13 May 1870 The river at Gundagai was 9.1metres above summer level and still rising with Tumut and Cooma also in flood.</li> <li>• Kiandra 139.7mm in 24h to 9am 13 May 1870.</li> <li>•14 May 1870 water reached 10.06metres at Wagga Wagga flooding houses.</li> <li>•15 May 1870 Dubbo – Heavy rain until 19 May when the water was level with the banks. 500 to 600sheep were lost at Colane.</li> </ul>
<p>Rainbands associated with upper troughs; 8-10 June 1870; 16-19 June 1870 and 22-25 June 1870. The details are in Appendix II.</p>	<ul style="list-style-type: none"> <li>•9 June 1870 Cannonbar (near Nyngan) - Macquarie River flood nearly as high as the May one. Water everywhere but little losses as stock were moved.</li> <li>•17 June 1870 Adelong Creek (near Tumut) Rapid rise in the creek with a few families forced to leave their houses. In the morning large logs came rushing down.</li> <li>•21 June 1870 Wagga Wagga water reached 9.22metres with the lower portion of the town submerged.</li> <li>•22 June 1870- 11.9metres at Dubbo equal 2nd worst flood (after 12.67metres 25 February 1955).</li> <li>•24 June 1870 - Tumut reported a flood with a great deal of fencing washed away and crops damaged or lost.</li> <li>•25 June 1870 -Report from Wilcannia - Wednesday 15th June there was heavy rain and on Tuesday 21 June a heavy thunderstorm with hail. The Darling has not fallen since March 19th; It was at a standstill for a few days and then it has been constantly and steadily rising and is now 33cms higher than the floods of 1867 and still rising. Nearly the whole country around Wilcannia is flooded.</li> </ul>
<p>Events July 1870 –weak East Coast Low 10-16 June and 21-22 June 1870 rainband with upper trough details in Appendix II.</p>	<ul style="list-style-type: none"> <li>•22nd July 1870: St. George: Very wet weather during past fortnight; rivers bankers; roads a perfect bog.</li> <li>•23rd July: Roma: Country in flooded state; roads almost impassable; torrents of rain nightly.</li> </ul>

<p>August 1870 Events series of unstable troughs producing Thunderstorms. Details in Appendix II.</p>	<ul style="list-style-type: none"> <li>•14th August 1870- Warwick: Condamine banker and Burnett's Bridge considerably under water.</li> <li>•22nd August 1870- Clifton - During a storm the meat preserving establishment was flooded to a very unusual extent; water to 1.5metres above floor level.</li> </ul> <p>Condamine- Water a metre deep on bridge over the Condamine; current running strongly. Inglewood: Heavy rain; one of the greatest floods in the Macintyre for many years.</p>
<p>A 986hPa low developed just south of Melbourne by 8 September 1870. There were 18 fatalities (7 at sea, 9 in floods and 2 in a collapsed mine). The storm is analysed in Section 7.</p>	<p>There were major floods with high ARIs as follows-</p> <ul style="list-style-type: none"> <li>•Wangaratta ARI 150-200years Largest known flood, magnitude uncertain;</li> <li>•Yarrawonga &amp; downstream ARI 150years.</li> <li>•Largest known flood in the Murray catchment, record flood heights in Echuca &amp; Mildura - Echuca wharf height 96.19metres AHD highest on record; Shepparton ARI 50years third largest flood; Rochester &amp; Echuca third largest flood.</li> <li>•Maryborough on Thursday 8th had widespread flooding and several houses were washed away.</li> <li>•Newstead on Thursday 8th had its heaviest floods ever flood with the river over a mile wide and water was flowing through the houses, causing much damage.</li> <li>•The highest flood ever known at Mansfield occurred on the morning of Thursday September. Mansfield is a small town in the foothills of the Victorian Alps and indicates the extreme rainfall which occurred in the Alps where there were no rain gauges at that time.</li> </ul>
<p>Rainband September 17-20 September 1870 culminating with Southerly Gale and rain Jervis Bay. Details in Appendix II.</p>	<ul style="list-style-type: none"> <li>•Kiandra 85.9mm in the 24hr to 9am 20 September 1870.</li> </ul>

<p>October 1870</p> <p>Thunderstorms Darling River District</p>	<ul style="list-style-type: none"> <li>•Around 4-5 October 1870 there were storms and heavy rain over a wide region of the Darling District. On Tuesday night 4 October the wind blowing strong from the North backed around to the west and at 9pm was broken by heavy peals of thunder and lightning and it rained in torrents without intermission through Wednesday. The downpour on Wednesday night increased in force and power as if from a cloud burst. The rainfall for two days was around 50mm and appeared to be widespread.</li> </ul>
<p>October NSW rainband event 24-25 October 1870 details in Appendix II.</p>	<ul style="list-style-type: none"> <li>•Wed 26 October 1870 - Adelong (12km west of Tumut) – water over the bridges with part of on washed away.</li> <li>•29 October 1870 - Young heavy rain and creeks flooded and a person drowned 31st.</li> </ul>
<p>October 24-30 1870</p> <p>Victorian weather system</p> <p>Tropical N to NE flow ahead of a front.</p> <p>Widespread major flooding in Northern and Western Victoria. The storm is analysed in Section 7.</p>	<p>Talbot (near Maryborough) – Flash 28 October. A 13yr old girl and a young woman (at Amphitheatre) were drowned. Several bridges were damaged, houses damaged, fences swept away and crops destroyed.</p> <ul style="list-style-type: none"> <li>• Avoca- Record flood Saturday morning (29 October) with large trees and fences swept away.</li> <li>• Maryborough- The inhabitants at McCallum’s Creek took refuge on the roofs of houses to escape the floods on Saturday (29 Oct).</li> <li>• Benalla- The Broken River attained its greatest height at 8pm Saturday (29th) and three-quarters of the town were underwater. The Benalla bridge was washed away.</li> <li>• Beechworth-Heavy floods throughout the district with the Murray, Ovens and other streams higher than 1867. Albury was partly submerged and the Ovens bridge at Wangaratta was carried away.</li> <li>• Ballarat- By 1am Saturday (29th) flood waters were running through the shops. Many people were saved in dramatic rescues though one man drowned, a child was swept away and another man was missing believed drowned.</li> <li>• Castlemaine – A severe thunderstorm Friday night 28 October caused floods in the town though with little damage but unfortunately a young boy was</li> </ul>

	<p>drowned. One house was badly damaged by lightning. Severe wind gusts also damaged houses.</p> <ul style="list-style-type: none"> <li>• Bullock Creek – A man was drowned in floodwaters.</li> <li>• Jamieson, Friday 28th the approaches to the Howqua-bridge were washed away.</li> <li>• Mansfield, Thursday. 27 October- Govett's bridge was swept away by the floods of Tuesday 25th.</li> <li>• Echuca, Thursday 27th The rivers Murray and Campaspe rose very rapidly, and part of the town was under water.</li> </ul>
<p>November Events rainband 11-14 November details in Appendix II</p>	<ul style="list-style-type: none"> <li>• 14 November 1870 Moulamein a fourth and higher flood than any hitherto has inundated nearly the whole town.</li> <li>• 14 November 1870 – The Yass River was in flood and the mail coach was washed away and the mailman nearly drowned.</li> <li>• 14 November 1870 – Wentworth- The river was rising.</li> </ul>
<p>East Coast Low 16-19 November 1870 details in Appendix II-</p>	<ul style="list-style-type: none"> <li>• 17 to 19 November 1870 - Warwick: Very heavy rain accompanied strong winds from the southward; the Condamine rose 4 feet above its usual level.</li> <li>• 26 November 1870 all the upper rivers were reported to be in full flood and the water was still rising at Wentworth.</li> </ul>
<p>Passage of the flood peaks.</p>	<ul style="list-style-type: none"> <li>• Darling River</li> </ul> <p>Following a period of extensive rainfall came the following report:-</p> <p>26 March 1870 - Bourke – The Darling is rising rapidly. The county is looking splendid and the rain is clearing.</p> <ul style="list-style-type: none"> <li>• Darling River rising</li> <li>• Wilcannia 21 April 1870 water reached a height of 9.2metres above summer level.</li> <li>• Bourke 21 April 1870 the water has risen 12.8metres. The whole country was up to a metre deep in water. In other areas several dams were washed away one on Mara Creek.</li> <li>• 22 April Darling River - Two men were drowned.</li> <li>• Murray River</li> </ul>

	<p>Sergeant at the Blanchetown police station South Australia, wrote in his diary: His record of the worst flood in the settled history of South Australia began as early as April 1870 that year when the sergeant wrote that the river was rising and steamers were moving again down the Darling with wool.</p> <p>•Darling River</p> <p>30 May 1870 Bourke reported that the Darling rose to 15.24metres (a record) above the summer level. Roads impassable and property at Tarcoon washed out.</p> <p>•Darling River</p> <p>25 June 1870 -Report from Wilcannia - Continual rain over the last eight days and for 48hours commencing on Wed 15th June there was heavy rain and on Tue 21 June a heavy thunderstorm with hail. The Darling has not fallen since March 19th; It was at a standstill for a few days and then it has been constantly and steadily rising and is now 3 feet higher than the floods of 1867 and still rising. Nearly the whole country around Wilcannia is flooded.</p> <p>•Sunday 3 July 1870- The Bourke mail arrived – The mailman said all the inhabitants had to evacuate to Mt Oxley. Latest from Bourke (17 July 1870) the river has fallen 1.22metres.</p> <p>•Murray Darling River</p> <p>Wentworth</p> <p>3 August 1870 – Wentworth passed the previous highest flood level (1867). Centre of town is safe but evacuations have been necessary further out.</p> <p>•Wilcannia</p> <p>20 August 1870 - Wilcannia - The Darling is at a standstill having risen 37 feet (11.3metres) - major flood level today is 10.4metres.</p> <p>•1 Sept 1870. At Wilcannia the water had fallen 25.4cm but was beginning to rise again. At the Darling and Murray Junction the volume is within 2.5cms of the greatest height attained on August 11 that is 8.08metres above the summer level and from that date it fell at 2.54cm per day until the 31st. On 3 September</p>
--	--

it commenced rising initially at 2.54cm per day with the greatest rate on the 11 September at 7.62cm per day then down to 5.08cm per day on the 12th.

•Bourke to Wentworth

9-11 September 1870 - Vessel left Brewarrina Friday 9 September, Bourke Saturday 10 September and Jandra 11 September then making down the Darling in 16 days. He reported Darling rising around 1.5 metres at Brewarrina – Bourke to Wilcannia falling – thence to Wentworth stationary. Above which the Darling current was stopped with the water being backed up by the Murray which had a record flood reported.

•Wentworth

13 September 1870 - Wentworth, after a subsidence of eighteen inches, the rivers commenced rising at Wentworth a few days ago, and the water is now nine inches higher than the highest point hitherto known, and still rising at 6cms per day. At Wahgunyah, Echuca, and Euston the Murray was still rising.

•September 26 1870 - Wentworth – water stationary and the large dam constructed by the government has kept the town dry. But outside the main centre many houses have been flooded and evacuated.

•Blanchetown and Mannum SA

30 September 1870 -The Bogan Hotel at Mannum has been flooded and closed for business.

•23-28 September 1870 here has been a great flood at Wentworth. One boy has been drowned. The population are about to abandon the town.

•1 October 1870 - At Blanchetown the river was 1.61km wide and at Mannum it was 2.13metres above summer level (highest since 1852).

• 5 October 1870 -Report from the east indicate there is more snow in the mountains than has ever before been known.

• Wentworth 4 October 1870 The flood is so high, that no one can get in and the water is still rising.

•4 October 1870 the river at Blanchetown has risen very fast for the past week and has reached a height 1.22metres above the 1867 flood.

	<p>•19 October 1870 News from Wentworth states that the Darling River is falling, but the Murray is still very high, and stations along the banks have suffered severely. Two homesteads below Blanchetown have swept away altogether.</p> <p>10 December 1870 At Blanchetown the flood was 0.46metres higher than the last rise and rising at 27cms per day.</p> <p>•12 December 1870 Mannum flood – ten days ago residents felt that the fall in the river was a genuine one and by 1 December the flood had fallen around one metre but since that date it has been rising rapidly. The Bogan Hotel has been useless for business since September 30 and now the water is washing over the window sills.</p> <p>•On 13 December 1870 Mounted Police Sergeant J.R. Ewens, officer in charge of the Blanchetown police station, wrote in his diary: ‘River higher than ever’. His record of the worst flood in the settled history of South Australia began as early as April that year when the sergeant wrote that the river was rising and steamers were moving again down the Darling with wool. After an extremely wet winter the river continued to rise until all the flat country along its banks was flooded drowning thousands of sheep and cattle. The Moorundie Police Station was destroyed and in Mannum rowboats could be taken in and out of the windows of the Bogan Hotel (now Mannum) and it was possible to step from the deck of the steamer Ariel on to the balcony of the hotel. The peak marked on a door at Walker’s Mill showed the waters to be roughly 4.57metres above normal and barges could sail up the main street to load flour at the mill.</p>
--	---

**Details of Impacts during 1956**

Events	Impacts
MDB January rainfall	January 1956 Rainfall in the MDB varied from average to very much above average with a record rainfall area in the Darling Downs see- <a href="http://www.bom.gov.au/jsp/awap/rain/archive.jsp?colour=colour&amp;map=decile&amp;year=1956&amp;month=1&amp;period=month&amp;area=md">http://www.bom.gov.au/jsp/awap/rain/archive.jsp?colour=colour&amp;map=decile&amp;year=1956&amp;month=1&amp;period=month&amp;area=md</a>
18-20 January 1956 Active monsoon trough with tropical NE flow into front over SE Australia.	<ul style="list-style-type: none"> <li>•Shepparton Fri 20 Jan 1956- 100mm of rain in the 2 days. 23.4mm 18th and 53.3mm 19th; Water was a foot deep in several streets. Scores of cars were abandoned.</li> <li>•The Broken River rose 4.1metres at Lima South – 3.05metres above flood level.</li> </ul>
Following from above 20-23 January 1956 Tropical Low near Mackay with trough to the south.	<ul style="list-style-type: none"> <li>•Macintyre Brook at Inglewood rose more than 3 metres above the level previously thought by engineers to be the flood extreme.</li> <li>•Near record flooding was also reported at Condamine, Texas and Surat with a large volume of water moving downstream into New South Wales.</li> <li>•Unprecedented floods were experienced in the Condamine and Macintyre rivers.</li> <li>•Heavy rain, Inglewood 275mm in 16 hours, Leyburn 150mm in 4 hours and general 250 to 325mm falls over the central Downs for the 72 hours ending 09:00am 23 January 1956.</li> <li>•Record river levels were reported at Goondiwindi on 22 January 1956, Riverton on 21 January 1956, Ranges Bridge on 22 January 1956, Miles on 22 January 1956, Tummaville on 22 January 1956 and Inglewood on 22 January 1956.</li> </ul>
MDB February rainfall	Feb 1956 Rainfall in the Northern Basin of the MDB was very much average with Pockets of Record rain in the Warrego, in the Namoi and in the eastern Darling Downs see- <a href="http://www.bom.gov.au/jsp/awap/rain/archive.jsp?colour=colour&amp;map=decile&amp;year=1956&amp;month=2&amp;period=month&amp;area=md">http://www.bom.gov.au/jsp/awap/rain/archive.jsp?colour=colour&amp;map=decile&amp;year=1956&amp;month=2&amp;period=month&amp;area=md</a>

<p>Inland trough developing 5-8 February 1956. Formed East Coast Low of 9-11 February 1956</p> <p>This was the largest flood in the Georges River since 1898.</p> <p>Rapid intensification of a tropical low near Tweed Heads 17-19 February 1956</p>	<ul style="list-style-type: none"> <li>•February 1956 The catchment areas of the Condamine and Macintyre rivers, where streams were still in a swollen state from the record January floods, experienced a succession of flood rains. •Highland districts received up to 750mm in 3 weeks, completely waterlogging the country and resulting in 100% run-off.</li> <li>•Three floods in the Macintyre catchment gave peak heights at Goondiwindi on 7th, 11th and 20th. This last reading and a peak at Texas on 19th, broke all existing records, but resulted from only 25 to 100mm of rain over the catchment.</li> <li>•The succession of 4 major floods in 4 weeks [including the January flood], was also a record. Roads and bridges were severely damaged, and a 50 metre gap torn in the bank of the Bonshaw Weir. Food drops were made necessary due to a general breakdown of transport.</li> <li>•The repeated flood rains have maintained very high levels in the Balonne and Barwon rivers for the whole month and towns are still isolated.</li> <li>•At Gunnedah 300 families fled to safety as the Namoi River rose. Major flooding occurred in Macintyre, Namoi, and Gwydir.</li> </ul>
<p>Record Rainfall March 1956</p>	<p>The NSW state wide historical March average rainfall is 48.97 mm. The March record is 155.31 mm which occurred during March 1956.</p> <p><a href="http://www.bom.gov.au/jsp/awap/rain/archive.jsp?colour=colour&amp;map=decile&amp;year=1956&amp;month=3&amp;period=month&amp;area=md">http://www.bom.gov.au/jsp/awap/rain/archive.jsp?colour=colour&amp;map=decile&amp;year=1956&amp;month=3&amp;period=month&amp;area=md</a></p>
<p>24 Feb-1 March 1956 Low developed near Lord Howe Island and moved towards the coast under the influence of the very large circulation of tropical cyclone <i>Agnes</i>. E-SE gales, 'mountainous seas', flooding Central NSW.</p>	<ul style="list-style-type: none"> <li>•Milguy (Myee) 39km E of Moree 89.4mm 3 March;</li> <li>Pallamallawa Post Office 29km E of Moree 93.5mm 3 March;</li> <li>Bingara 72km SE of Moree 78.7mm 3 March;</li> <li>May Vale 61km E of Narrabri 113mm 3 March;</li> <li>Yallaroi 85.6mm 3 March 66km SSE of Goondiwindi</li> <li>•Canberra 63.0mm 3 March 1956 caused major local flooding. The Australian Forestry school received 50.0mm in less than an hour. Water flooded shops at Kingston. There was also flooding in the suburbs.</li> </ul>

<p>2-3 March Trough crossed NSW with a tropical moisture feed in from Agnes.</p>	
<p>March 1956 5-6 Trough near Adelaide developed into a low in the Eastern Bight. Tropical flow into Victoria from Large TC Agnes approaching Townsville.</p>	<ul style="list-style-type: none"> <li>•March 1956 The heavy run-off from the February floods on the Darling Downs maintained high levels in the Balonne River for the whole month.</li> </ul>
<p>Tropical Cyclone Agnes Hit Townsville on the 6 March – heavy rainfall affected southern states as the moisture from Agnes penetrated there and interacted a major front over 6-9 March 1956. Agnes then moved down to the W Qld/NSW border by 12 March also bring heavy rain into the MDB. Record rain fell over the Darling.</p>	<ul style="list-style-type: none"> <li>•24h rainfall Nyah (Northern Vic) 74.9mm 6th March 1956 March record 1899 to present.</li> <li>•Ultima (near Swan Hill) 90.9mm 6th March 1956 March record 1897 to present.</li> <li>•WIMMERA -Donald Post Office 93.5mm 6<sup>th</sup>, all-time record 1884 to 1966; Litchfield 84.2mm 6th March record 1882 to 1978.</li> <li>•March 1956 rainfall SW Qld - Charlotte Plains 50km east of Cunnamulla 75.7mm 9th and 10<sup>th</sup>; Bollon 219.8mm 10-12<sup>th</sup>;</li> </ul>
<p>13-14 March 1956 Northerly to northeasterly tropical inflow into trough SW Qld (ex Agnes) and across Southern NSW and Victoria developing into a complex low over Tasmania.</p>	<ul style="list-style-type: none"> <li>•Tue 13 March 1956 Very heavy rain brought a flood into Cooma at 4pm with cars swept down the main Street and flooded houses and shops. One house was swept away. 125mm fell in Cooma in 2hr causing Cooma Creek to rise 12 feet in half an hour reaching the highest level in 25 years.</li> <li>•14 March 1956 11.9metres at Dubbo equal 2nd worst flood with 1870 (12.67metres 25 February 1955).</li> <li>•SW Qld Bollon 76.9mm 14 and 15th;</li> <li>•Thu 15 March 1956 Levees were strengthened at Forbes, Warren and North Dubbo with the brunt of the Lachlan, Macquarie and Bogan Rivers</li> </ul>

	<p>expected early on 16 March. 300 people were evacuated from North Dubbo when the Macquarie broke its banks. Wellington and Canowindra were also affected. Levees were being raised at Nyngan. At Cowra the shopping Centre was devastated by floods.</p> <ul style="list-style-type: none"> <li>•Fri 16 March 1956 A record flood Peak threatening Warren; Dubbo flood expected early 17 March RAAF dropped 3,500 sandbags; Narromine low lying areas evacuated; river at Wellington reached 46feet 2 inches and families evacuated and water has reached the main street.</li> </ul>
19-20 March 1956 Large high moved into Tasman Sea with tropical NE winds and strong pressure gradient across Southern Qld and NSW.	<ul style="list-style-type: none"> <li>•Wed 21 March 1956 a woman and twin babies was trapped by floodwaters in her cottage at Mole Station 60 mile from Nyngan. Floods also around Goodooga (30km SW of Hebel)</li> <li>•Fri 23 March 1956 Brewarrina District (97km ENE of Bourke) flooded- Homesteads isolated.</li> <li>•March 1956 rainfall SW Qld - Augathella 148.6mm 20th; Charleville 104.6mm 19-21st ; Charlotte Plains 50km east of Cunnamulla 181.4mm 19 and 20th ;</li> </ul>
Bourke Levels	<ul style="list-style-type: none"> <li>•Bourke flood levels 13.77metres 22 March 1956 compared with 15.24metres above summer level in 1870.</li> </ul>
0000UTC 29 March 1956 active monsoon trough with intense low below 990hPa developing Southwest Qld 0000UTC 30 March ahead of 500hPa low. Strong surface front through SW Qld and W NSW/VIC by 0000UTC 1 April 1956	<ul style="list-style-type: none"> <li>•Mon 1 April 1956 A record flood Peak was halfway between Augathella and Charleville – Floodwaters in the Maranoa were expected to overwhelm 2,500 sheep at Woodlands Station 80miles from St George.</li> <li>•Heavy rains over western and south-western districts at the end of March caused heavy flooding in all south-west rivers from the Maranoa and lower Balonne rivers to Cooper Creek in the first half of the month. The floods reached serious proportions in the Warrego River, where flood peaks were generally the highest this century. Charleville peaked on 3rd [highest on record], Wyandra peaked on 4th [highest since 1910], and Cunnamulla peaked on 7th [highest since 1890].The evacuation of some homes was necessary, towns were isolated and stock losses reported.</li> </ul>

	<ul style="list-style-type: none"> <li>•March 1956 rainfall SW Qld - Augathella 103.3mm 29-30th; Charleville 140.5mm 29-30th; Charlotte Plains 78.0mm 30 and 31st; Bollon 52.8mm 30 and 31st;</li> </ul>
April rainfall in the MDB	<p>April 1956 rainfall in the MDB - mostly average to very much above average with highest on record around NE Highlands of VIC.</p> <p><a href="http://www.bom.gov.au/jsp/awap/rain/archive.jsp?colour=colour&amp;map=decile&amp;year=1956&amp;month=4&amp;period=month&amp;area=md">http://www.bom.gov.au/jsp/awap/rain/archive.jsp?colour=colour&amp;map=decile&amp;year=1956&amp;month=4&amp;period=month&amp;area=md</a></p>
<p>14 -16 April 1956 982hPa low west of Tasmania and</p> <p>16-19 April 1956 Low moved slowly to the south of Tasmania over the period.</p> <p>25-26 April 1956 1007hPa low Central NSW moved east with 1000hPa low east of Coffs Harbour.</p>	<p>NE VIC from late March system- Beechworth 72.4mm 1<sup>st</sup>; Callaghan Creek 72.6mm 1<sup>st</sup>; Myrree 77.0mm 1<sup>st</sup>; Stanley State Forest 110.2mm 1<sup>st</sup>;</p> <p>Wooragee 86.4mm 1<sup>st</sup>; Yackandandah 79.0mm 1<sup>st</sup>; Eurobin 110.0mm 1<sup>st</sup>; Mt Buffalo Chalet 160.3mm 1<sup>st</sup>; Bogong 95.0mm 1<sup>st</sup>;</p> <ul style="list-style-type: none"> <li>•Major Flood Mitta Mitta River.</li> <li>•Prolonged heavy 24h rainfall-- Mount Buffalo Chalet 31.2mm 10th 34.3mm 11th 147.3mm 15th 58.9mm 16th 95.3mm 17th 50.5mm 18th 75.4mm 18<sup>th</sup>;</li> <li>•Bogong 95.0mm 1st 27.4mm 11th 89.4mm 14-15th 32.0mm 16th 42.4mm 17th 29.2mm 18th 57.4mm 19th 31.5mm 20th 47.2mm 21<sup>st</sup>;</li> <li>•Mount Beauty 80.8mm 15th 19.1 35.6 24.9 32.0 28.4mm 20th 24.9mm 21<sup>st</sup></li> <li>•Thursday night 19 April 1956 60 homes flooded as mile wide Ovens River struck Wangaratta. The Mitta Mitta River was a foot deep in Tallangatta and Corryong had extensive flooding from the Murray.</li> <li>•Sunday night 13 April 1956 20 Charlton homes had water lapping the doors from a record flood in the Avoca River.</li> </ul> <p>Western Darling Downs 25-26 April 1956- Columboola 60.5mm 26th; Woodlea 54.6mm 26th; Belah Park 54.9mm;</p>
May 1956 rainfall in the MDB.	<p>May 1956 rainfall in the MDB mostly above to very much above average with highest on record in Western Victoria and nearby NSW. Also small pockets of highest on record in SW and NE NSW.</p>

	<a href="http://www.bom.gov.au/jsp/awap/rain/archive.jsp?colour=colour&amp;map=decile&amp;year=1956&amp;month=5&amp;period=month&amp;area=md">http://www.bom.gov.au/jsp/awap/rain/archive.jsp?colour=colour&amp;map=decile&amp;year=1956&amp;month=5&amp;period=month&amp;area=md</a>
<p>1956 May 1-3</p> <p>1000hPa low developed Gippsland and moved east.</p> <p>Ahead of this development a trough lay from Central Qld to Western VIC with northeasterly airstream feeding into it.</p>	<ul style="list-style-type: none"> <li>•24h rainfall Nyah near Swan Hill (076044) 78.7mm 2nd May 1956 May record 1899 to present; Pira Wild Horse Plains 70.6mm 2nd; Budgerum East 77.5mm 2nd; Meatian 74.7mm 2nd;</li> <li>•Tue 1 May 1956 Floodwaters from the Peel and Namoi Rivers are expected in Gunnedah at 7am 2 May.</li> <li>•Wagga Wagga floods 1956 5 May 8.31metres</li> <li>•Heavy rain Southern Tablelands Goulburn Monaro 1-2nd May 1956.</li> </ul>
<p>1956 May 10 -16.</p> <p>10-11 May 1956 1003hPa low developed over NW NSW –</p> <p>13-14 May 1956 985hPa low South of WA moved into Bight deepened to 975hPa 15 May and weakened to 995hPa 16 May. One fatality.</p>	<ul style="list-style-type: none"> <li>•Major flood Campaspe River Rochester ARI &gt;100years</li> <li>•Major flood Goulburn River Shepparton ARI 20years</li> <li>•A policeman was swept away and drowned in floods at Avoca on Wed 16 May.</li> <li>•Near Maryborough, two bridges - one at Bet Bet and one at Eddington - were washed: away, - and many sheep drowned.</li> <li>• Maryborough-Avoca road was blocked by 6ft. of water Wed night 16 May.</li> <li>•At the tiny township of Tatyoon, the Fiery Creek had reached its record height for 25 years.</li> <li>•Foundations of a new concrete bridge being built over the Hall's Gap Creek, as well as bridge - building machinery, were swept away.</li> <li>•Sunday 13 May 1956 Tilpa (115miles south of Bourke) 250 people are likely to be marooned for the next few months in the township's worst flood since 1890.</li> <li>•Sunday 20 May 1956 police rescued 40 people from River flats between Mooroopna and Shepparton during the weekend. The Goulburn River rose rapidly at Shepparton during the weekend with flooding expected.</li> </ul>

	<ul style="list-style-type: none"> <li>•May 1956 Sharp stream rises were reported in the upper Condamine River, with sustained flooding in the lower Balonne and Moonie rivers.</li> </ul>
<p>11–13 May 1956 Low Inland low intensified off Southern NSW Coast moving away Long fetch SE gales 13<sup>th</sup>. Flood rains South Coast.</p>	<ul style="list-style-type: none"> <li>•Heavy rain Southern Tablelands Goulburn Monaro 13-14<sup>th</sup> May 1956. Wagga Wagga floods 19 May 8.46metres.</li> </ul>
<p>DARLING MOVEMENT APRIL/MAY</p>	<ul style="list-style-type: none"> <li>•26 April 1956 a 400mile long and 20mile wide inland sea extends from Bourke to Menindee isolating Wilcannia where the Darling has reached a depth of 30 feet.</li> <li>•Mon 28 May 1956 The Darling was 14 mile wide extending from Pooncarie to Wentworth (about 100km).</li> </ul>
<p>June 1956 rainfall in the MDB</p>	<p>June 1956 rainfall in the MDB mostly above to very much above average with highest on record parts of the ACT and nearby.</p> <p><a href="http://www.bom.gov.au/jsp/awap/rain/archive.jsp?colour=colour&amp;map=decile&amp;year=1956&amp;month=6&amp;period=month&amp;area=md">http://www.bom.gov.au/jsp/awap/rain/archive.jsp?colour=colour&amp;map=decile&amp;year=1956&amp;month=6&amp;period=month&amp;area=md</a></p>
<p>A 1005hPa low near Lord Howe Island 9 June 1956 Rapidly intensified to below 994hPa and moved near the coast east of Wollongong in 24 hours Gusts reached 135km/h (73 knots) at Sydney Observatory on 10 June which is a June record for that station.</p>	<ul style="list-style-type: none"> <li>•16 June 1956 Murrumbidgee floods Gundagai 8.89m (12<sup>th</sup>), Wagga Wagga 9.12m (16<sup>th</sup>) Narrandera 8.11m Darlington Point 7.21m</li> <li>•Rainfall 125.5mm Braidwood 10<sup>th</sup>; 99.6mm Michelago 10<sup>th</sup>; Kyeema 98.3mm 9-10/6/1956 Cathcart 73.7mm 10<sup>th</sup>;</li> </ul>
<p>East Coast Low 24–26 June 1956 Eight fatalities East Coast Low north of Fraser</p>	<ul style="list-style-type: none"> <li>•Rainfall Captains Flat 75.7mm 25<sup>th</sup>; Cathcart 71.6mm 25<sup>th</sup>, 108.2mm 26<sup>th</sup>; Hall (Canberra) 64.8mm 25<sup>th</sup>; Pierces Creek Forestry – 20km W of</li> </ul>

<p>Island moved to Gold Coast 24-25 June 1956 and then amalgamated with inland low to form an intense depression off the South Coast of NSW 26 June. Strong NE-E gradient, gales, rough seas.</p>	<p>Canberra 79.2mm 25<sup>th</sup>; Fairlight Station 22m WNW Canberra 79.0mm 25<sup>th</sup>; Braidwood 113.0mm 25<sup>th</sup>;</p> <ul style="list-style-type: none"> <li>• Rainfall Central Highlands- Wellwood (near Orange) 69.6mm 25<sup>th</sup>;</li> </ul> <p>Running Stream 52km NNE Bathurst 104.6mm 24-25<sup>th</sup>; Orange 76.5mm 25<sup>th</sup>; Oberon 86.1mm 25<sup>th</sup>; Mullion Creek 21km N of Orange 75.2mm 25<sup>th</sup>;</p> <ul style="list-style-type: none"> <li>•Sun 24 June 1956 The Murray at Albury was 16feet 1inch 4.88m. 5.50m is major level.</li> <li>•Mon 25 June the Molonglo River reached 17feet (5.18m) – the highest since 1948.</li> <li>•Wed 27 June 1956 – 500 people were evacuated from North Wagga and another 150 also left their homes as warnings were issued for the Lachlan and Murrumbidgee Rivers. Families were evacuated in Coonamble and floods have isolated families around Dubbo and Narromine.</li> <li>•The Lachlan river at Forbes was 31foot 9inches (9.68m) and rising. Major level 10.55m.</li> <li>•At Goondiwindi was 5 feet under water (Wed 27 June) with the fifth flood in 6 months.</li> <li>•Fri 29 June – North Wagga flooded with only 100 people remaining in their homes.</li> </ul> <p>29 June Murrumbidgee floods Wagga 9.58metres; Narrandera 8.2metres; Darlington Point 7.3metres;</p> <ul style="list-style-type: none"> <li>•Lower areas in Forbes were 2 feet under water.</li> <li>•Sunday 1 July 1956. The SA section of the Murray was 2 miles wide in places.</li> <li>•2 July 1956 Murrumbidgee floods Gundagai 9.46m, Wagga Wagga 9.58m Narrandera 8.70m Darlington Point 7.47m.</li> </ul>
<p>July 1956 rainfall in the MDB</p>	<p>July 1956 rainfall in the MDB - average grading to very much above average to highest on record west of Tambo (SW Qld) to ACT.</p> <p><a href="http://www.bom.gov.au/jsp/awap/rain/archive.jsp?colour=colour&amp;map=decile&amp;year=1956&amp;month=7&amp;period=month&amp;area=md">http://www.bom.gov.au/jsp/awap/rain/archive.jsp?colour=colour&amp;map=decile&amp;year=1956&amp;month=7&amp;period=month&amp;area=md</a></p>

<p>July 6-8 1010hPa low near Adelaide with tropical inflow to east, moved to a 1000hPa low southeast of Tasmania.</p> <p>Low deepened moved from SW NSW to east of Sydney 11-12 July 1956</p> <p>16-17 July 1956 1000hPa low south of Ceduna moved to near Mt Gambier heavy rain through Riverina</p>	<ul style="list-style-type: none"> <li>•Qld -July 1956 Continued wet weather over southern inland districts has maintained high levels in all south-western rivers. The Warrego River was reported to be 13 kilometres wide at Cunnamulla. A number of stations on the Warrego, Bulloo and Paroo rivers reported the highest July levels on record. Drier weather in the second half of the month in these areas is at last allowing streams to subside.</li> <li>•Rainfall Kynnersley (81km SSW of Charleville) 72.0mm 7<sup>th</sup>; Quilberry (83km SSW of Charleville) 73.4mm 7<sup>th</sup>; Wyandra 66.3mm 7<sup>th</sup>; Charlotte Plains 50km E of Cunnamulla 63.5mm 7<sup>th</sup>; Sherwood Park 99km NE of Quilpie 61.2mm 7<sup>th</sup>;</li> <li>• Rainfall 7 July 1956- SW SLOPES NSW - Batlow 65.0mm 7<sup>th</sup>; Bago 71.1mm 7<sup>th</sup>; Laurel Hill 63.0mm 7<sup>th</sup>; Kunama 71.6mm 7<sup>th</sup>; Jounama 63.5mm 7<sup>th</sup>;</li> <li>•Wagga Wagga floods 1956 10 July 8.99metres</li> <li>•Sun night 8 July seventy Echuca homes were flooded, 25 families had already left their homes.</li> <li>• Mildura: Every available man, woman, and child raising the levee bank protecting the low-lying part of the town.</li> <li>•Rainfall 12 July 1956 -Southern Tablelands NSW - Bombala 62.2mm 12<sup>th</sup>; Cathcart 72.9mm 12<sup>th</sup>; Braidwood 65.5mm SNOWY Guthega 50.8mm 12<sup>th</sup>;</li> <li>• Shepparton: People living on the Broken River, two miles south of the town, evacuated their homes before 2ft. of water swirled through them Monday 9th.</li> </ul> <p>The Goulburn was almost 8km wide, stretching from Shepparton to well beyond Mooroopna.</p> <ul style="list-style-type: none"> <li>• Albury: People living on low-lying flats between Wodonga and Albury were moved. It was estimated 70,000 acres are under water.</li> <li>• Wangaratta: About 50 homes in low-lying parts of the town were cut off.</li> </ul>

	<ul style="list-style-type: none"> <li>• Echuca: The Campaspe River had been backed up by the flooded Murray, forcing 35 families from their homes near the river junction.</li> </ul> <p>Night of 11 July brown floodwater rushed through 100 homes at West Echuca.</p> <ul style="list-style-type: none"> <li>• Two families fled their homes at the northern end of Wangaratta Sunday.</li> <li>• Rochester had its worst flood for 40 years early Sunday when the Campaspe rive reached a height of 7.1 metres. An Inland sea 10 mile long and 1.5 miles wide covered grazing land in wheat farms to a depth of 3ft.</li> <li>• The Avoca river was on 45cm below the record flow level, of May 17 this year at Charlton Sunday night. .</li> <li>• At Rodsborough six miles from Maryborough floodwaters were six miles wide Sunday night.</li> </ul> <p>•24hour rainfall-VICTORIA - Lower NE- Strathbogie 71.4mm 7th, 18.5mm 8th; Lima East 68.3mm 7th, 23.4mm 8th; King Valley 59.7mm 7th, 30.2mm 8th; Stanley State Forest 63.5mm 7th, 11.7mm 8th; NE Highlands- Dandongadale 63.5mm 7th, 21.3mm 8th; Archerton 75.7mm 7th, 18.0mm 8th; Mt Buffalo Chalet 70.1mm 7th, 26.2mm 8th; Whitlands 30.0mm 3rd, 65.8mm 7th, 16.5mm 8th; North Central - Bendigo Channel 67.3mm 7th; Campbell's Creek 45.7mm 7th; Musk 47.8mm 7th; Trentham 44.2mm 7th; Redesdale 47.8mm 7th; Pipers Creek 46.5mm 7th; Lower North - Korong Vale 39.9mmm 7th; Wychitella South 38.6mm 7th;</p> <ul style="list-style-type: none"> <li>•Sun 8 July 1956 Rochester the flooded Campaspe River gave the town the worst flood for years. 20homes and 13 shops were awash.</li> <li>•Monday 9 July 1956 200 people have been evacuated from North Wagga (The third evacuation in three weeks.)</li> <li>•Tue 17 July 1956 Floods in Northern Vic NSW and SA have forced 1100 families to abandon their homes. In Buronga (Opposite Mildura) glass house crops were swept away; Barham NSW 500people isolated; around</li> </ul>
--	---

	<p>Merbein 25 families isolated; Wentworth 6 families evacuated; Echuca 200 families homeless.</p> <ul style="list-style-type: none"> <li>•Mon 16 July 1956 Deniliquin – Edwards River 30feet 11.5inches (9.4metres which is the major flood level) and river was rising and there was very heavy rain. North Deniliquin was flooded with 150 houses submerged.</li> <li>•Wagga Wagga flood level 20 July 1956 was 8.59metres</li> <li>•Sun 22 July 1956 NSW Murray towns of Barham and Wakool 6000 soldier settlement farms were half under water.</li> </ul>
<p>24-26 July 1956 995hPa Low complex south of Adelaide and Melbourne moved into SW Tasman Sea with series of fronts</p>	<ul style="list-style-type: none"> <li>•Tue 24 July 1956 Residents at Moulamein were working around the clock to reinforce Levee banks the river was 6.04metres (major level 6.1metres). Rainfall Bowning 66km NNW of Canberra 52.8mm 24<sup>th</sup>; Rainfall 2days to 26 July 2018 -Batlow 84km ESE Wagga 77.0mm in; Billapaloola State Forest 68km W of Canberra 89.0mm Yellowin 29km WSW Canberra 78.5mm;</li> <li>•The Murrumbidgee at Balranald had its worst flood for 65years.</li> <li>•Wagga Wagga flood 28 July 1956 8.71metres.</li> <li>•Sunday 29 July 1956 The river at Mildura reached 10.9metres.</li> <li>•Bourke flood levels were 13.61metres at 31 July 1956 compared with 15.24metres above summer level in 1870.</li> </ul>
<p>South Australian Floods</p>	<ul style="list-style-type: none"> <li>•In early June, Renmark’s 21st Street was closed off, and by the end of the month, the Sturt Highway between Renmark and Paringa was also out of action. The situation was eased by the introduction of a rail shuttle service between the two towns.</li> <li>•By mid-August, 1,500 people had been evacuated, leaving some 800 men, women and children to battle the rising floodwaters. Shops and businesses operated with minimum staff and for reduced hours, so that as many people as possible were available to fill and transport the sandbags.</li> </ul>

	<ul style="list-style-type: none"> <li>•The flood waters hit Mannum in July 1956. Six hundred homes in the district were flooded, as well as two hundred holiday shacks. Some were totally destroyed.</li> <li>•The Murray River peaked (Harrison 1957) on 15 August 1956 when the gauge at Wentworth read 9.78metres. Later it read 12.3metres at Morgan in South Australia.</li> <li>•From Harrison (1957) The main peak in the Darling River occurred at Menindee on 2 September 1956 when the gauge there read 10.06metres. This peak was due to three peaks at Bourke 13.72metres 22-23 March 1956, 11.89metres 25-28 June 1956 and 13.41metres 31 July- 6 August 1956.</li> <li>•Below Menindee the flow of the Darling is divided between the main river and the Great Anna Branch. The peak reached the lower end of the Anna Branch on the 5 October by which time the Murray had somewhat subsided. In the main Darling River the peak of 9.45metres reached Burtundy (50km NNE of Wentworth) on 12 September 1956 as the Murray was dropping. The peak in the Darling River was a month later than the peak in the Murray and the peak in the Great Anna Branch a further two weeks later.</li> <li>•At midnight on 22 August 1956 the level of the River Murray at Renmark reached 9.32metres. It was thought this was the peak but the next day the water rose further to 9.33metres although for the first time since 15 June it then remained stationary. The Murray would peak at 10.2m in Renmark as the gauge disappeared underwater.</li> <li>•Some areas were flooded up to 100 kilometres from the natural flow of the river.</li> <li>•River heights were back to normal by Christmas.</li> </ul>
--	---

## Appendix II

### Details of Weather events during 1870

## **January 1870 Events**

### **First weather system** –rainband with heavy areas with thunderstorms 3-4 January 1870

Rainband affected Warrego with nearest station Roma reporting rain late 3 January through to 4 January.

Torrential rain in the Warrego producing the biggest flood in years. Previously the country was very dry and devoid of grass. Same system at Wanganella (148km SW Hay) 50.8mm 3rd. Rain NSW MDB 3 January

Thunderstorms at Hay, Moulamein, Urana, Deniliquin, Balranald, Euston, Wentworth, Forbes, Dubbo Narrabri and Wagga Wagga. NSW MDB - 4 January –Rain at Tenterfield, Glen Innes, Inverell, Armidale, Tamworth, Gunnedah, Murrurundi, Yass.

### **Second weather system** –rainband with heavy areas with thunderstorms 26 January 1870

26 January 1870 - Rain NSW MDB -Wanganella (148km SW of Hay) 50.8mm 3rd; 63.5mm 26th; Forbes, Young, Wellington, Dubbo, Bathurst, Orange, Cooma, Yass, Gundagai, Tumut, Kiandra, Albury, Balranald, Hay, Deniliquin, Urana, Wagga Wagga and Cooma.

27 January 1870 - NSW MDB Rain - Gundagai, Yass, Bombala, Cooma, Tumut, Kiandra, Wellington, Dubbo, Bathurst, Orange, Young, Forbes, Tamworth, Murrurundi, Gunnedah, Narrabri and Armidale.

## **March 1870 Events**

### **Tropical Cyclone 2-10 March 1870**

This was a prolonged period of rainfall with some heavy falls in Queensland and NSW due to tropical air moving over the area as a Tropical cyclone moved southwards from 2 -12 March 1870.

Rainfall reported from Tropical Cyclone effects.

2 March 1870 - NSW MDB Rain – Tenterfield, Narrabri, Armidale, Tamworth, Bathurst, Wellington, Dubbo, Wellington, Forbes, Young, Orange, Urana, Deniliquin, Wagga Wagga, Moulamein, Euston , Hay, Balranald, Wentworth, Hay, Goulburn (heavy rain), Queanbeyan, Bombala, Cooma, Yass, Albury. QLD MRB Rain; Allora, Dalby, Drayton, Roma, Warwick.

3 March 1870 - NSW MDB Rain – Glen Innes, Gunnedah, Narrabri, Bathurst, Wellington Orange.

4 March 1870 - NSW MDB Thunderstorms - Glen Innes, Inverell, Armidale, Tamworth, Mudgee, Wellington, Dubbo, Tamworth, Bathurst. Rain - Bombala, Cooma, Kiandra, Yass.

5 March 1870 NSW MDB rainfall with some thunderstorms - Glen Innes, Inverell, Yass, Wellington, Orange, Dubbo, Young.

6 March 1870 - No data NSW Sunday. QLD MDB Rain – Allora, Condamine, Dalby, Roma, Taroom and Warwick.

7 March 1870 - NSW MDB rainfall with some thunderstorms - Tenterfield, Glen Innes, Inverell, Narrabri heavy Rain, Armidale, Gunnedah, QLD MDB Rain – Allora, Condamine, Dalby and Roma;

8 March 1870 QLD MDB – Allora, Condamine, Dalby, Warwick and Roma; NSW see Figure 1.

9 March 1870 QLD MDB – Warwick and Roma; NSW see Figure 1.

10 March 1870 QLD MDB – Condamine, Roma; NSW see Figure 1.

### **East Coast Low 12-18 March 2018**

Rainfall reported East Coast Low

- 12 March 1870- NSW MDB rainfall with some thunderstorms- Gunnedah, Inverell, Narrabri, Tamworth, Young (storm) and Goulburn. Boggabri recorded 35.8mm.
- 14 March 1870- NSW MDB rainfall – Tenterfield, Armidale. QLD MRB – Condamine, Dalby, Roma (heavy rain), Warwick, Taroom.
- 15 March 1870- NSW MDB rainfall – Tenterfield, Glen Innes Armidale, Inverell, Narrabri, Tamworth, Glen Innes
- 16 March 1870- NSW MDB rainfall – Tenterfield, Glen Innes Armidale, Inverell, Tamworth, Glen Innes, Dubbo, Bathurst, Wellington.

### **Event 2-6 April Rainband with upper trough.**

Rainfall reported

- 2 April 1870 – NSW MDB Rain - Forbes, Wellington.
- 4 April 1870 – NSW MDB Rain – Narrabri, Forbes, Orange, Dubbo, Bathurst, Wellington, Yass, Young, Grenfell and Cooma.
- 5 April 1870 - NSW MRB Rain - Cooma, Yass, Queanbeyan, Armadale, Glen Innes, Tamworth , Dubbo, Orange, Wellington (heavy rain), Grenfell, Forbes, Cassilis, Bathurst, Grenfell, Kiandra, Gundagai and Cooma. Thunderstorms – Deniliquin, Hay, Tumut.
- 6 April 1870 -- NSW MRB Rain- Armidale, Glen Innes, Tenterfield, Wellington, Dubbo.

**Events June 1870—Rainbands associated with upper troughs -8-10 June 1870; 16-19 June 1870 and 22-25 June 1870.**

**First June event Rainfall reported.**

8 -10 June 1870 rain band associated with upper trough no coastal low.

- 8 June 1870 NSW MDB rain- Deniliquin, Albury, Tumut, Gundagai, Queanbeyan, and Yass.
- 9 June 1870 NSW MDB rain- Young, Moulamein, Grenfell, Forbes, Orange, Mudgee, Dubbo, Wellington, Bathurst, Albury, Bombala, Yass, Gundagai.
- 10 June 1870 NSW MDB rain Gundagai, Forbes, and Moulamein.

**Second June event Rainfall reported.**

16 -19 June 1870 rain band associated with upper trough no coastal low.

16 June 1870 NSW MDB rain- Balranald, Euston, Moulamein, Hay, Deniliquin, Dubbo, Wellington, Glen Innes.

- 17 June 1870 NSW MDB rain- Hay, Deniliquin, Urana, Wagga, Grenfell, Young , Forbes, Albury, Tumut, Gundagai, Yass, Goulburn, Bombala.
- 18 June 1870 NSW MDB rain- Wagga, Grenfell, Young, Forbes, Orange, Dubbo, Wellington, Mudgee, Bathurst, Tumut, Yass, Goulburn, Armidale, Inverell , Tamworth, Glen Innes, Tenterfield.

**Third June Event Rainfall reported.**

22 -25 June 1870 rain band associated with upper trough no coastal low.

- 22 June 1870 NSW MDB rain- Wellington, Orange, Dubbo, Forbes, Young, Grenfell, Albury, Gundagai, Narrabri, Inverell, Glen Innes, Armidale, Tamworth.
- 23 June 1870 NSW MDB rain- Gunnedah.
- 24 June 1870 NSW MDB rain- Wagga, Urana, Young, Grenfell, Forbes, Wellington, Orange, Dubbo, Mudgee, Kiandra, Tumut, Gundagai, Yass.
- 25 June 1870 NSW MDB rain- Orange, Young, Grenfell, Forbes, Narrabri, Gunnedah, Albury, and Tumut.

**Events July 1870 –weak East Coast Low 10-6 June and 21-22 June 1870 rainband with upper trough.**

**First July Event 10-16 July 1870 development of a weak east coast low.**

- 15 July 1870 QLD MDB Rain – Condamine, Toowoomba. NSW MDB Rain - Goulburn, Orange Wellington Merriwa, Thunderstorms Tamworth.
- 16 July 1870 QLD MDB Rain – Condamine, Roma.

**Second July event 21-22 July 1870 Rain Band upper trough no surface low.**

•21 July 1870 QLD MDB Rain- Condamine, Dalby, Toowoomba, Warwick. NSW MDM Rain – Bathurst, Forbes.

•22 July 1870 QLD MDB Rain- Condamine, Dalby, Roma, Toowoomba, Warwick. NSW MDB Rain – Forbes.

**August 1870 Events- series of unstable troughs producing Thunderstorms.**

12-22 August 1870 rainfall reported.

13 August 1870 -QLD MDB Rain – Warwick, Toowoomba.

14 August 1870 -QLD MDB Thunderstorms - Warwick, Toowoomba, Allora rain calm; Durah (between Chinchilla and Mundubbera), Roma.

15 August 1870 QLD MDB Thunderstorms – Toowoomba, Warwick.

16 August 1870 - QLD MDB Thunderstorms - Toowoomba and Warwick;

17 August 1870 - QLD MDB Thunderstorms – Toowoomba, Warwick and Dalby.

18 August 1870 QLD MDB Thunderstorms - Dalby and Durah.

19 August 1870 mostly fine reports W to SW winds;

22 August 1870 QLD MDB Thunderstorms –Toowoomba and Warwick.

**Rainband September 17-20 September 1870 culminating with Southerly Gale and rain Jervis Bay.**

17 September 1870 NSW MDB Rain- Glen Innes; Inverell; Armidale Tamworth; Narrabri; Bombala;

Kiandra(snow); Wellington; Orange;

19 September 1870 NSW MDB Rain- Yass; Tumut; Kiandra; Gundagai; Orange; Forbes; Young; Wagga Wagga; Grenfell. Thunderstorm – Goulburn; Bathurst; Blue Mts.

20 September 1870 – No rain MDB and Southerly Gale and rain Jervis Bay.

**October rainband events 24-25 October 1870**

24 October 1870 - NSW MDB Rain - Queanbeyan, Cooma, Tumut, Kiandra, Albury, Gundagai, Wellington, Orange, Grenfell, Forbes, Wagga Wagga, Urana, Deniliquin, Hay, Moulamein, Dubbo.

25 October 1870 – NSW MDB Rain- Gundagai. Bathurst, Queanbeyan, Bombala, Kiandra, Cooma, Dubbo, Wellington, Orange, Forbes, Grenfell, Young, Wagga Wagga, Urana,

**November Events rainband 11-14 November**

12 November 1870 - NSW MDB – Rain Euston, Balranald, Moulamein, Wagga Wagga, Young, Grenfell Forbes, Orange, Dubbo, Bathurst, Yass, Tumut, Gundagai, Armidale.

### East Coast Low 16-19 November 1870-

16 November 1870 – NSW MDB Rain - Tenterfield, Glen Innes, Inverell, Armidale, Blue Mts.

17 November 1870 – NSW MDB Rain – Tenterfield, Glen Innes, Inverell, Armidale, Blue Mountains Heavy rain. QLD MDB Rain- Roma.

18 November 1870 – NSW MDB Rain – Armidale, Tenterfield, Goulburn, Queanbeyan, Bombala, Yass, Gundagai, Tumut, Blue Mountains, Bathurst, Wellington, Orange, Forbes, Grenfell, Young heavy rain, Wagga Wagga. QLD MDB Rain- Roma.

19 November 1870 – NSW MDB Thunderstorm- Glen Innes, Inverell. Rain – Armidale Queanbeyan, Kiandra, Blue Mountains heavy rain, Wellington, Dubbo, Orange, Forbes, Young, Moulamein, Balranald, Euston, Wentworth.

### Appendix III

A list of the official major floods and un-official (marked by \*) major floods identified in this study, together with the type of meteorological event that triggered the flood and the associated death tolls 1860 to 2016.

No.	Location	Date	Type	Freshwater flooding fatalities
1*	Major Floods Thomson, Macalister and Avon Rivers people took refuge in trees.	17.02.1863	ECL	10
2*	Gippsland homesteads flooded.	21.03.1870	ECL	2
3*	Gippsland houses washed away.	13.05.1870	ECL	1
4*	Gippsland	19.06.1871	ECL	1
5*	Gippsland offices swept away.	29.05.1879	ECL	2
6*	South Gippsland bridges and culverts washed away.	15.04.1885	ECL	1
7*	Possible Major Flood Tambo River	17.04.1886	ECL	-
8*	Tambo River Tongio inundated	24.06.1890	ECL	1
9	Yarra ARI 60year.	12.07.1891	ECL	7
10	Maribyrnong River and Gippsland	2.08.1891	ECL	7
11	Avoca River.	30.05.1893	Low	1
12*	Yarra River, Record flood Coleraine.	25.09.1893	Low	-
13	Gippsland Lakes ARI 70years	29.12.1893	ECL	3
14*	Gippsland crops destroyed, roads flooded and a bridge destroyed.	22.06.1896	ECL	.
15*	Gippsland widespread crop damage, bridges swept away or damaged. Campers flooded out	6.02.1897	ECL	-
16*	Merriman Creek Gippsland major flood	4.04.1900	ECL	-
17*	Moe, Bunyip and Koo-wee-rup – many dwellings flooded.	16.04.1900	ECL	-

18*	Gippsland record rainfall and widespread flooding 18 <sup>th</sup> & 24 <sup>th</sup> up to a metre flooding in many towns.	18.10.1905	Series of ECLs	-
19*	Severe flood damage Seymour area. Severe flash flooding Collingwood & Hawthorn. Record rainfall east Gippsland.	11.03.1906	ECL	1
20	Record daily rainfall to 156.7mm East Gippsland	7.09.1908	ECL	
21*	Houses flooded Traralgon.	12.06.1909	ECL	-
22*	Snowy River worst flood since 1893. Severe flood Omeo and Genoa.	15.03.1911	ECL	2
23	Record 24h rainfall Sale Balook Flood Bairnsdale Walhalla and South Gippsland	18.01.1911	ECL	
24*	Farms flooded Moe, Yarragon and Bunyip.	14.07.1914	ECL	-
25	Echuca, Murchison, Seymour & Shepparton ARI 100years. Maribyrnong River, Gippsland Record floods in some areas and Wimmera River.	23.09.1916	ECL	15
26*	Melbourne around 400 houses inundated	5.03.1919	TC ET ECL	3
27*	Bruthen - part of town under water.	27.08.1919	ECL	-
28	Tambo River Bruthen- Largest flood on record.	29.01.1920	ECL	-
29*	Orbost highest flood since 1893 (most rain from NSW)	29.07.1922	ECL	1
30	Yarra	12.10.1923	ECL	2
31	Bunyip River, Yarra River.	26.08.1924	ECL	-
32*	Moonie Ponds Creek Maribyrnong River- Houses flooded.	21.10.1924	ECL	-
33*	Orbost possible Major flood and in South Gippsland Bridge swept away.	10.05.1925	ECL	-
34*	Bruthen Main Street flooded; Snowy River flood caused widespread damage	12.07.1925	ECL	-
35*	West Gippsland houses flooded and widespread flood damage.	30.09.1927	ECL	1
36*	Bruthen, Maffra, Bairnsdale, Orbost and Omeo widespread farm damage.	28.03.1928	ECL	-
37*	West Gippsland widespread stock & crop losses.	3.06.1930	ECL	-
38*	Yarra, storm surge Beaconsfield Parade flooded hundreds of cars. Record Rainfall Melbourne.	21-03.1931	ECL	-
39*	Lorne camping ground inundated. Great Ocean Road, landslides, all-time record rainfall.	27.03.1932	ECL	-
40	Orbost flood 24h totals Dargo 163.8mm Bindi 170.2mm	24.06.1933	ECL	(18 at sea)
41	Koo Wee Rup ARI >150years, Yarra, Yea, Latrobe and Moe Rivers all ARI 100 years	1.12.1934	ECL	20 and (17 at sea)
42*	Gippsland many farms flooded.	10.02.1935	ECL	-
43*	Trafalgar, Rosedale, Sale, Stratford and Traralgon- Extensive flooding – Houses in towns flooded.	20.04.1935	ECL	-
44*	West Gippsland Houses abandoned.	30.04.1935	ECL	-
45*	Gippsland heavy crop and stock losses. Campers Trapped & Rainfall records broken.	26.12.1935	ECL	-(31 at sea)
46*	N Victoria and Gippsland. Shops houses flooded Murchison.	11.01.1936	ECL	-
47	Bairnsdale ARI 100years;	24.06.1936	ECL	-
48	Koo Wee Rup ARI 100years, Merri Creek.	19.10.1937	ECL	1
49*	Orbost, Bruthen crops destroyed. Snowy 3cm below major level.	17.03.1938	ECL	-
50*	All-time record 24h rainfall West Gippsland	15.05.1944	ECL	-
51*	Lakes Entrance 500 evacuated - Bairnsdale Bruthen, and Paynesville bridges washed away.	1.01.1949	ECL	-
52*	Possible Major flood Genoa River. Major flood level Orbost.	9.02.1950	ECL	-
53*	Snowy River 7.3m (major flood at Orbost).	22.10.1950	ECL	-

54*	Elwood Canal flooded 30 Brighton homes. Evacuations from floods at Gisborne and Traralgon; Record 24h rainfall East Sale.	18.02.1951	ECL	-
55	Gippsland Lakes ARI 100years largest flood on record; Barwon River.	20.08.1951	ECL	1
56*	East Gippsland Princes Highway cut Cann River and Orbost. Army Ducks supplied farmers.	27.09.1951	ECL	-
57	Geelong ARI 80 years; Batesford ARI 60 years; Swifts Creek ARI 55years.Koo Wee Rup; Yarra, Snowy and Tambo Rivers.	16.06.1952	ECL	3
58*	Evacuations due floods at Orbost, Bruthen Traralgon and Seaspray. Major flood Mitchell River.	12.12.1952	ECL	-
59*	Major Flood Cann River	6.05.1953	ECL	-
60*	Moe River sent a muddy surge of water four feet high, across the valley at Trafalgar and Moe inundating homes. People evacuated at Sale.	20.10.1953	ECL	-
61*	Yarram Shops houses flooded.	9.11.1954	ECL	-
62	Bacchus March ARI 50years; Werribee, Fairfield;	20.11.1954	ECL	2 (5 others)
63*	Orbost & Genoa Princes Highway cut and families isolated. Around major flood level Orbost.	27.06.1956	ECL	-
64*	Record Rainfall Yarra River catchment	22.04.1960	ECL	-
65*	Just below major flood at Orbost.	27.06.1960	ECL	-
66*	Record rainfall Gippsland	2.03.1961	ECL	-
67*	Record rainfall possible floods South Gippsland.	20.01.1962	ECL	-
68*	Flood havoc to most Melbourne suburbs from record rainfall.	29.01.1963	ECL	-
69*	Record 24hour rainfall Gippsland to 224mm.	4.10.1966	ECL	-
70*	All-time Record rainfall possible severe flooding South Gippsland.	30.06.1967	ECL	-
71*	Major flood Mitchell River Glenaladale 6.37m	1.06.1970	ECL	-
72	Macalister River at Lake Glenmaggie 8.64m Major Flood ARI 50 years. Major flood Mitchell River	30.01.1971	ECL	-
73*	Yarra River at Burnley 3.12m; All-time record daily rainfall NE Victoria to 206.8mm;	8.11.1971	ECL	-
74*	Major Flood Snowy River Jarrahmond.	26.05.1974	ECL	-
75*	Major Flood Snowy & Cann Rivers	12.06.1974	ECL	-
76*	Major flood Mitchell River Bairnsdale	3.07.1974	ECL	-
77*	Major Flood Snowy River	30.08.1974	ECL	-
78*	Near Major flood Cann River.	25.06.1975	ECL	-
79*	Major Flood Thomson River at Cowwarr Weir 6.0metres;	17.10.1976	ECL	-
80*	Major Flood at Moe.	27.07.1977	ECL	-
81*	Orbost. Genoa River all-time daily record rainfall to 223.1mm;	2.04.1978	ECL	-
82*	Genoa River record rainfall throughout catchment	20.05.1978	ECL	-
83	Sale ARI 100years; Seaspray ARI 50years; Rosedale ARI 30years; Traralgon ARI 30years; Orbost; Bairnsdale; Stratford.	2.06.1978	ECL	-
84*	Added to Gippsland Floods	18.06.1978	ECL	-
85*	Major Flood Powlett & Bass Rivers.	29.06. 1980	ECL	-
86*	Lakes Entrance 204mm 25th all-time daily rainfall record. Also many May records.	24.05.1981	Tropical Low – ECL	-
87*	Major Flood Cann River	4.05.1983	ECL	-
88	Melton ARI 70years, Werribee ARI 50years, Horsham and Little River	15.10.1983	ECL	-
89*	South Gippsland Major floods. Orbost major flood.	29.07.1984	ECL	-
90	Dandenong Creek Police Road ARI 45years.	19.09.1984	ECL	-

91*	Cann River 3.19m at Weeragua (major flood)	14.09.1985	ECL	-
92*	Major Flood Bairnsdale	25.10.1985	ECL	-
93*	Major Flood Snowy River Basin Creek	27.11.1985	ECL	-
94*	Major flood 8.74m at Orbost	12.12.1985	ECL	-
95*	Major flood Snowy River at Buchan. Record 24hour rainfall to 195.4mm;	17.11.1988	ECL	-
96	Yea	11.06.1989	ECL	-
97	Mitchell River Glenaladale ARI 55years, Boisdale – Stratford ARI 50years and Bairnsdale.	21.04.1990	ECL	-
98*	South Gippsland Major floods	12.10.1990	ECL	-
99*	Major flood Snowy River.	13.06.1991	ECL	-
100*	Major Flood Snowy River	12.07.1991	ECL	-
101	Seaspray ARI 70years, Traralgon ARI 50years, Sale Rosedale and Casterton.	15.09.1993	ECL	-
102*	Major Flood Macalister River	23.10.1995	ECL	-
103	Bacchus March ARI 60years, Werribee River, Geelong and Batesford.	6.11.1995	ECL	-
104	Mitchell River Glenaladale ARI 60years, Tambo River Swifts Creek ARI 50years, Cann River and Stratford. Snowy River 7.85m at Orbost.	23.06.1998	ECL	1
105*	Haines Junction 268.6mm 22nd. Also Cape Schanck 238.6mm 22nd. Gippsland Genoa 157.0mm 22nd Apr record. Erica 130.0mm 22nd Apr record.	22.04.2001	ECL	-
106	2002 February records on 11 <sup>th</sup> Gippsland all time Combiobar 146.8mm Feb records Mallacoota 136.0mm, Club Terrace 161.4mm;	11.02.2002	ECL	
107	108.8mm 24 <sup>th</sup> 2004 East Sale all time daily record also Stratford and Meerlieu and Glenaladale near Bairnsdale	24.04.2004	ECL	
108	Gippsland -Glenmaggie ARI 100years, Glenaladale ARI 50years; The Channel ARI 40years, Cowwarr and Lakes Entrance.	27.06.2007	ECL	-
109	Macalister River Glenmaggie	4.11.2007	ECL	-
110	Nov 23 2008 Major flood Tambo River at Swifts Creek 4.45m Ramrod Creek 5.59m Battens Landing 5.40m	23/11/2008	ECL	-
111*	12-14 December 2008 rainfall records Western VIC	13/12/2008	ECL	
112	Creswick, Charlton, Wangaratta and Shepparton.	3.09.2010	ECL	-
113*	Major Flood Tarwin River	13.04.2011	ECL	-
114	Traralgon.	21.07.2011	ECL	-
115	Mitchell Macalister and Avon Rivers.	10.08.2011	ECL	1
116*	Evacuations Lakes Entrance and flash flooding Geelong.	26.11.2011	ECL	-
117	Orbost area.	8.03.2012	ECL	-
118	Bairnsdale, Traralgon, Licola and Stratford.	5.06.2012	ECL	
119*	Traralgon, Heyfield and Yarram.	13.06.2013	ECL	-
120*	Bemm River Princes Highway	8.04.2015	ECL	-
121	Jarrahmond, Buchan, Orbost, Glenaladale	7.07.2016	ECL	-