Jacobs

# Maribyrnong Flood Event October 2022- Post Event Analysis

Document no: Jacobs Group (Australia) Pty Ltd
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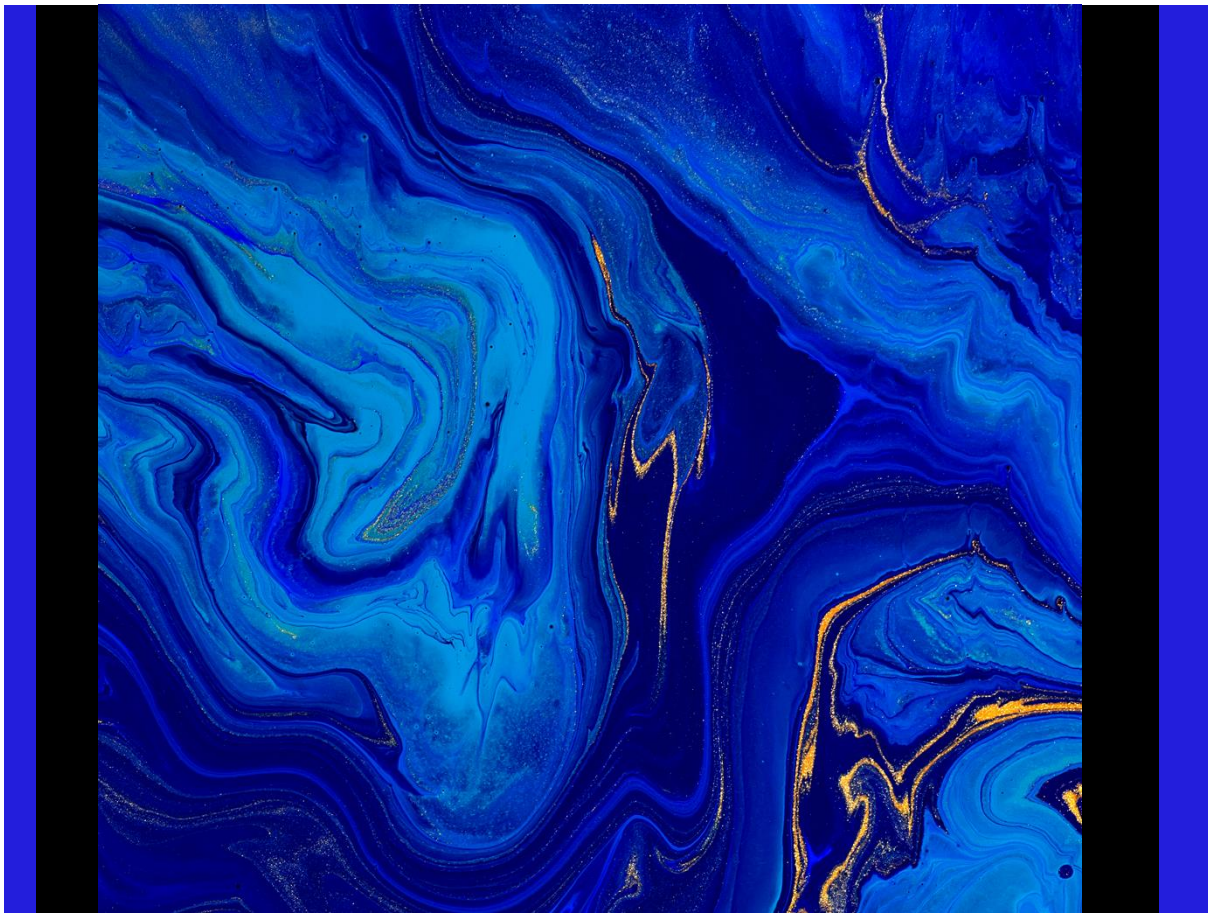
Melbourne Water

28 March 2023



# Maribyrnong Flood Event October 2022- Post Event Analysis

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## Document history and status

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# Contents



# Appendices




The data obtained for this report was gathered during October 2022 except where explicitly stated. Due to the collecting organisation standard quality control procedures, this data may have been revised and updated since it was obtained for this report. For this reason, it is expected there will be some discrepancies between the data presented in this report and the data available from the references herein.

**Important note about your report**

Melbourne Water commissioned this report immediately following the October 2022 flood event with the aim of understanding the conditions that led to the event and the magnitude of the event.

Jacobs' sole purpose in preparing this report is to provide near live information regarding the October 2022 flood event on the Maribyrnong River and should not be relied on for design, emergency management response or any other purposes. It has been prepared to understand the magnitude and drivers of the October 2022 Maribyrnong River flood event together with an analysis against existing publicly available flood mapping information. Given the nature of the information relied upon in this report, unverified live and near live data, it has been necessary to presume this information is accurate. Jacobs makes no representations as to the accuracy or completeness of this information. However, it is expected this information will change, which will require the observations in this report to be reviewed and reconsidered. Jacobs notes:

- The intended audience for this report was Melbourne Water technical staff.
- Data and information within this report has been sourced from publicly available information which has been assumed to be accurate except where explicitly stated.
- Due to the live nature of the data used in this report, any analysis based upon this may require the report to be re-evaluated.
- The report should be read in full, with no excerpts to be representative of the findings.
- While all due skill and attention has been taken in collecting, validating and providing the data, Jacobs shall not be liable in any way for loss of any kind including damages, costs, interest, loss of profits or special loss or damage, arising from any error, inaccuracy, incompleteness or other defect in the data.
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- The report has been prepared exclusively for Melbourne Water (2022) and Jacobs accepts no liability for any use or reliance on the report by third parties.


The data obtained for this report was gathered during October 2022 except where explicitly stated. Due to the collecting organisation standard quality control procedures, this data may have been revised and updated since it was obtained for this report. For this reason, it is expected there will be some discrepancies between the data presented in this report and the data available from the references herein.

# Summary

Flooding in the Maribyrnong River catchment on the 13th and 14th October 2022 followed significant rainfall across the catchment in the preceding days. Analysis and synthesis of available data on the event obtained in October 2022 (except where otherwise noted) and existing information has found:

- The rainfall event was relatively modest compared to the river flow event, with higher rainfall totals corresponding to rarer rainfall events occurring in the upper catchment. In the upper catchment the event has been estimated at between the 2% (1 in 50) and 20% (1 in 5) Annual Exceedance Probability (AEP) rainfall events for the 48-hour period across the 13th and 14th October 2022.
- Analysis of antecedent conditions found the Maribyrnong River catchment experienced significantly wetter than average conditions for Spring prior the storm event on the 13-14th October 2022. The 13-14th event was preceded by a storm event on the 6-8th of October 2022 of approximately 30-40 mm. This earlier storm event contributed to the wetter than usual conditions, which exacerbated the runoff response of the catchment.
- Review of available information on water stage and streamflow at Deep Creek at Darraweit Guim, the Maribyrnong River at Keilor and the Maribyrnong River at Maribyrnong has shown:
    - Deep Creek at Darraweit Guim reached a peak stage of 7.22 m on 13th October 2022, the highest since records began in 1975. At-site Flood Frequency Analysis (FFA) for the Deep Creek at Darraweit Guim gauge was undertaken including a peak flow estimate for the recent event. The peak flow of 280 $m^3/s$ was close to a 1% AEP event (300 $m^3/s$). The Deep Creek catchment is the largest contributing catchment area to flows in the Maribyrnong River.
    - The Maribyrnong River at Keilor recorded a peak water stage of 8.64 m on 14th October 2022, the highest recorded stage since the 1974 event. At-site FFA for the Maribyrnong River at Keilor gauge was undertaken including a peak flow estimate for the recent event. The peak flow rate of 768 $m^3/s$ was just above a 2% AEP (760 $m^3/s$) event.

      The FFA peak flow estimates calculated are greater than the flood quantiles presented in the Maribyrnong River Flood Mitigation Study (Melbourne Metropolitan Board of Works,1986) by between 5-10%. This increase is due to two significant events occurring in the period since 1986. In the period 1871 to 1986 (115 years) there were two observed peak flows in excess of 650 $m^3/s$ (1906 - rank 1 and 1974 - rank 3). In the period since (36 years) there have been an additional two events greater than 650 $m^3/s$ (1993 - rank 4 and 2022 - rank 2).
    - The Maribyrnong River at Maribyrnong peak water stage reached 4.22 m on 14th October 2022. A review of historic information indicates this event is the 3rd highest based on recorded river stages, following 1906 (4.5 m, rank 1) and 1916 (4.26 m, rank 2), and was slightly higher than the 1974 event (4.2 m, rank 4). Whilst the 1916 event was 40 mm higher than the October 2022 event, there is uncertainty associated with historic records due to catchment changes and the passage of time. Overall, the October 2022 event is considered to be the 2nd largest in terms of flow.

As these observations and findings are based on live or near live data, they may change if the data is updated due to collecting organisations' standard quality control procedures.

# Abbreviations and definitions

| | |
|---|---|
| **ARR 2019** | 2019 release of Australian Rainfall & Runoff Guidelines. |
| **AEP** | Annual Exceedance Probability. The probability that an event of a given size will be equalled or exceeded in a given year. |
| **ARI** | Average Recurrence Interval. The inverse of the AEP expressed as a return period. For instance, the 1% AEP is equivalent to the 100 year ARI event. |
| **FFA** | Flood Frequency Analysis. |
| **Hydrograph** | A time series of flow which changes at each timestep and naturally captures the peak flood flow. |
| **m AHD** | Meters Australian Height Datum. |
| **$m^3/s$** | Cubic metres per second (a measure of flow). |

**Terminology between ARI and AEP**

This report references both ARI and AEP although the AEP terminology has generally been preferred to remain consistent with current guidance in Australian Rainfall and Runoff (2019). In some cases, information prepared prior to 2019 has been used which used the ARI terminology and has been retained here to avoid misunderstanding.

In accordance with ARR 2019, AEP is the probability of an event being equalled or exceeded within a year and may be expressed as either a percentage (%) or 1 in X. For example, a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year.

Average Recurrence Interval (ARI) was a term used previously to define the probability of design flood events (ARR, 1987) and was defined as the average period between occurrences equalling or exceeding a given value. The use of terms such as “recurrence interval” and “return period” are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years. The term ARI has only been applied when referencing information developed prior to the release of ARR 2019.

# Introduction

Melbourne Water have commissioned Jacobs to prepare a post-flood analysis in the Maribyrnong River catchment that considered rainfall and river conditions prior to and during the October 2022 flood event using publicly available information. This information has been obtained soon after the event and in some cases before standard quality control procedures had been completed. For this reason, it is expected that some data will change.

The analysis focused on Deep Creek at Darraweit Guim and the lower Maribyrnong River, in and around Maribyrnong Township. The report is structured as follows:

- Rainfall analysis – including characterisation of the rainfall received in the Maribyrnong catchment.
- Analysis of antecedent conditions, or the wetness of the catchment prior to the rainfall event.
- River conditions – including analysis on river flow and stage in the Maribyrnong catchment.
- Observations compared to the 1% AEP (Annual Exceedance Probability) flood mapping available for Darraweit Guim and Maribyrnong Township areas.

## Purpose

The purpose of this report was to provide an assessment of the antecedent conditions, the rainfall events and the magnitude of the flood event based on available information in October 2022 except where explicitly stated. It is acknowledged that some information was live or near live information and this information will change upon review and quality control by the originating organisation.

## Background

Flooding in the Maribyrnong River catchment on the 13th and 14th October 2022 followed significant rainfall across the catchment in the preceding days. Darraweit Guim was reported by Macedon Ranges Shire Council as the shire's hardest hit town in the flood event, with multiple houses, businesses and facilities severely damaged by floodwaters[1,2]. Downstream at Maribyrnong Township, Ascot Vale and Keilor, the event resulted in approximately 100 properties being flooded (ABC News[3], 2022 [accessed on 17/10/2022]). The resulting peak water reached a stage of:

- 7.22 m at the Deep Creek at the Darraweit Guim gauge (230100A) with a flow rate of 280 $m^3/s$
    - Water stage and flow data were obtained from Bureau of Meteorology (The Bureau[4], 2022 [accessed 8/12/2022]).
- 8.64 m at the Maribyrnong River at Keilor gauge (230200) with a flow rate of 768 $m^3/s$ (updated from initial estimate of 827 $m^3/s$ (The Bureau[5], 2022 [accessed on 17/10/22]))
    - The stage was greater than the highest stage in the rating table prior to this event.
    - It is understood that new gauging measurements were collected by Melbourne Water during the recent event, and the rating table was revised and extended. The updated estimate of 768 $m^3/s$ is therefore considered a reliable estimate.
- 4.22 m at the Maribyrnong River at Chiefly Drive Maribyrnong gauge (587015/230106) with a flow rate of around 770 $m^3/s$

[1] https://ncreview.com.au/2022/10/25/darraweit-guim-hardest-hit-by-floods-in-macedon-ranges/ [accessed 12/12/22]

[2] https://www.miragenews.com/council-responds-to-flood-crisis-and-urges-878471/ [accessed 14/12/2022]

[3] https://www.abc.net.au/news/2022-10-14/melbourne-floods-cause-evacuations-in-maribyrnong-and-werribee/101534804 [accessed 17/10/22]

[4] https://www.bom.gov.au/waterdata/ [accessed 8/12/2022]

[5] https://data.water.vic.gov.au/ [access 17/10/22]

  - Water stage data obtained from Bureau of Meteorology Rainfall and River conditions site (The Bureau[6], 2022 [accessed on 17/10/22]).
  - The flow rate was obtained from Melbourne Water for a water level of 4.18m (Melbourne Water[7], 2022 [accessed on 17/10/22]).

- It is noted that, with the exception of Melbourne Water's estimate of the Maribyrnong River at Keilor, the recorded gauge data still needs to be quality controlled and will change in the future.

[6] http://www.bom.gov.au/vic/flood/port_phillip.shtml [accessed 17/10/22]

[7] https://www.melbournewater.com.au/water-data-and-education/rainfall-and-river-levels#/reader/230106A [accessed 17/10/22]

# Flood History

The Maribyrnong River has a long history of flooding, as detailed in Figure 1, with the last major event recorded in September 1993. In the upper Maribyrnong catchment, the Deep Creek catchment last experienced a significant flood event in 2011.

## Darraweit Guim

Darraweit Guim is a rural village at the junction of Deep Creek and Boyd Creek, located in the upper Maribyrnong River catchment. The area is thought to be named after an Aboriginal expression meaning a meeting of two creeks[8]. Darraweit Guim is known to have experienced historic flooding, including in the years 1906[8], 1916[9], 1934[8] and 2011[10,11], resulting in significant damage. Darraweit Guim Primary School has experienced flooding over multiple years, with the most serious damage understood to have occurred in 2011, where school grounds became completely inundated[10].

## Maribyrnong Township

The 1974 event in the Maribyrnong River catchment had estimated damages of between $12 and $15 million (Melbourne and Metropolitan Board of Works (MMBW)[12], 1986) (monetary value estimated in 1986). The peak flow rate of the 1974 event reached approximately 710 $m^3/s$ and had an estimated Annual Exceedance Probability (AEP) of 2% (MMBW, 1986). The largest flood on record was in 1906 with an estimated flow of 880 $m^3/s$ and was reported to have a 1 in 140 AEP (MMBW, 1986).

[8] https://www.victorianplaces.com.au/darraweit-guim [accessed 12/12/2022]

[9] Trove (2022) *The Age* 'In Kilmore District' from Wed 25 Oct 1916 [accessed at https://trove.nla.gov.au/newspaper/article/155065643?searchTerm=flood%20darraweit%20guim on 12/12/2022]

[10] https://www.darraweitguimps.vic.edu.au/page/19/School-History [accessed 13/12/2022]

[11] https://midlandexpress.com.au/latest-news/featured/2022/10/18/roads-closed-as-rivers-burst-banks/ [accessed 20/12/2022]

[12] Metropolitan Board of Work (MMBW) Maribyrnong River Flood Mitigation Study (March 1986)

| Height (metres) | Impact/level |
|---|---|
| 4.50m | 8 September 1906<br>Highest recorded flooding affecting the Maribyrnong Flood Plain. |
| 4.26m | 22 September 1916<br>Second highest recorded flooding |
| 4.20m | 14 May 1974<br>Although the third highest flood level in recorded history, it caused the greatest degree of damage to residential, industrial and public utilities. |
| 3.83m | 15 September 1993<br>Anglers Tavern lounge and bistro areas under nearly two metres of water, and a further 50 residences flooded over floor level. |
| 2.9m | Major flood level<br>Tram services along routes 57 & 82 and bus services 468 & 952 along Raleigh Road likely to be impacted. |
| 2.83m | 10 November 1954<br>Maribyrnong River breaks its banks causing 200 families to be temporarily homeless. More than 60 rescued by Army boats. |
| 2.3m | Moderate flood level<br>Maribyrnong River Trail flooded at various locations. Burton Crescent Reserve impacted. |
| 2.21m | 14 January 2011<br>Flooding of the lower floor at the Anglers Tavern commenced. Closure of Chifley Drive, Plantation Street and nearby adjoining roads. Infrastructure improvements then implemented and have reduced the risk of similar floods having the same impact. |
| 1.7m | Minor flood level |

**Figure 1: Maribyrnong River at Maribyrnong historic stages from SES[13] (2018).**

[13] SES Local Flood Guides: Maribyrnong City Council, Maribyrnong township flood gauge [accessed at: https://www.ses.vic.gov.au/plan-and-stay-safe/flood-guides/maribyrnong-city-council on 17/10/22]

# Rainfall

A significant rainfall event occurred on the 13th and 14th October 2022 across the Maribyrnong River catchment. Rainfall data was obtained from eight Melbourne Water daily rainfall gauges[14] within the catchment and a catchment average rainfall value was calculated from Silo data[15].

Silo is a database of Australian climate data from 1889 to the present. Silo data is a gridded rainfall dataset (Jeffrey et al., 2001[16]) available through the Long Paddock website. It is created by interpolating observational data obtained from the Bureau of Meteorology and other providers. There are approximately 15 daily rainfall stations across the Maribyrnong catchment used in the interpolation, depending on data availability. The grid is created at a 0.05° latitude by 0.05° longitude (approximately 5 km × 5 km) resolution.

Both Melbourne Water and Silo provide daily rainfall over a 24-hour period to 9:00am. These restricted 24-hour totals (9:00am to 9:00am) may underestimate the 24-hour maximum rainfall total for an event. Correction factors for this have been developed by Durrant and Bowman (2004)[17] - the 24-hour event factor is 1.15 and 48-hour event factor is 1.11. Further analysis of rainfall events using pluviograph data, that records rainfall in sub-daily increments, can be undertaken when the data become available from various data collecting organisations.

Table 1 shows the 24-hour rainfall depths for the 13th October 2022 and 14th October 2022 as well as the 48-hour total for the 13th and 14th October 2022. This table also shows the approximate AEP of the recorded rainfall using Intensity Frequency Duration (IFD) data for the specific location obtained from the Bureau[18]. Initial analysis using the Durrant and Bowman (2004) correction factors did not significantly change the AEPs listed in Table 1 hence the data is presented uncorrected. The AEPs of the rainfall totals are expected to be rarer if the 24- or 48-hour period considered is shifted to capture the most intense rainfall over the given period (rather than the period to 9:00am each day). The location of the gauges is shown in Figure 2. Comparison of rainfall depths to the catchment centroid IFD's are shown in Figure 3, Figure 4 and Figure 5.

The information in Table 1 shows the following:

- The 24-hour rainfall totals had more frequent AEPs.
- The 48-hour rainfall totals were rarer, particularly in the upper catchment.
- Overall, the rainfall was relatively modest, particularly in the lower catchment.
- North Lancefield had the rarest event with the 48-hour rainfall estimated between the 2% AEP (1 in 50) and 1% AEP (1 in 100) event.
- The upper catchments for Jacksons Creek (Mt Macedon) and Deep Creek (Lancefield North and Darraweit) have estimated 48-hour rainfall AEPs of greater than 50% (1 in 2).

[14] Melbourne Water Rainfall and River Level https://www.melbournewater.com.au/water-data-and-education/rainfall-and-river-levels#/ [accessed 17/10/22]

[15] Silo Australian climate data [accessed at https://www.longpaddock.qld.gov.au/silo/ on 24/10/22].

[16] Jeffrey, S.J., Carter, J.O., Moodie, K.B. and Beswick, A.R. (2001). Using spatial interpolation to construct a comprehensive archive of Australian climate data, Environmental Modelling and Software, Vol 16/4, pp 309-330.

[17] Durrant, J., Bowman, S. (2004) Estimation of rare design rainfalls for Western Australia. Application of the CRC-FORGE method. Department of Environment, Surface Water Hydrology Report Series Report No. HY17. Dec 2004.

[18] http://www.bom.gov.au/water/designRainfalls/revised-ifd/ [accessed 16/10/22]

**Table 1: Various gauged rainfall depths for daily gauges which record data from 9am to 9am 13th and 14th October 2022.**

| Rain gauge station# | 24-hour rainfall 13/10/22 | | 24-hour rainfall 14/10/22 | | 48-hour rainfall 13/10/22 - 14/10/22 | |
|---|---|---|---|---|---|---|
| | Recorded Rainfall in mm | Approx. AEP | Recorded Rainfall in mm | Approx. AEP | Recorded Rainfall in mm | Approx. AEP |
| Lancefield North (587026) | 68.0 | 20% to 10% | 74.8 | 10% | 142.8 | 2% to 1% |
| Bulla (230102) | 9.4 | < 62.3% | 21.2 | < 62.3% | 30.6 | < 62.3% |
| Sunbury (230104A) | 14.2 | < 62.3% | 26.2 | < 62.3% | 40.4 | < 62.3% |
| Clarkefield (230211A) | 22.4 | < 62.3% | 32.4 | < 62.3% | 54.8 | 62.3% to 50% |
| Rosslynne (230103A) | 26.2 | < 62.3% | 22.2 | < 62.3% | 48.4 | < 62.3% |
| Mt Macedon (587126) | 71.4 | 50% to 20% | 60.2 | 50% to 20% | 131.6 | 10% |
| Romsey (587117) | 36.8 | < 62.3% | 43.4 | 62.3% | 80.2 | 50% to 20% |
| Darraweit (230100A) | 30.2 | < 62.3% | 44.6 | 50% to 20% | 74.8 | 20% |

# Rainfall data sourced from Melbourne Water Rainfall and River Level [https://www.melbournewater.com.au/water-and-environment/water-management/rainfall-and-river-levels#/ accessed 17/10/2022]

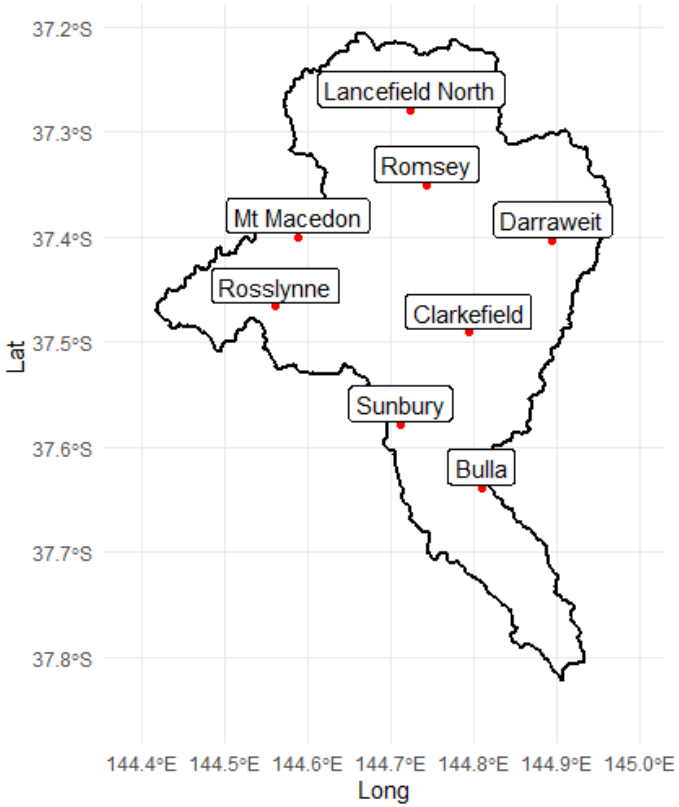



**Figure 2: Location of rainfall gauges listed in Table 1 within the Maribyrnong River catchment (black outline).**

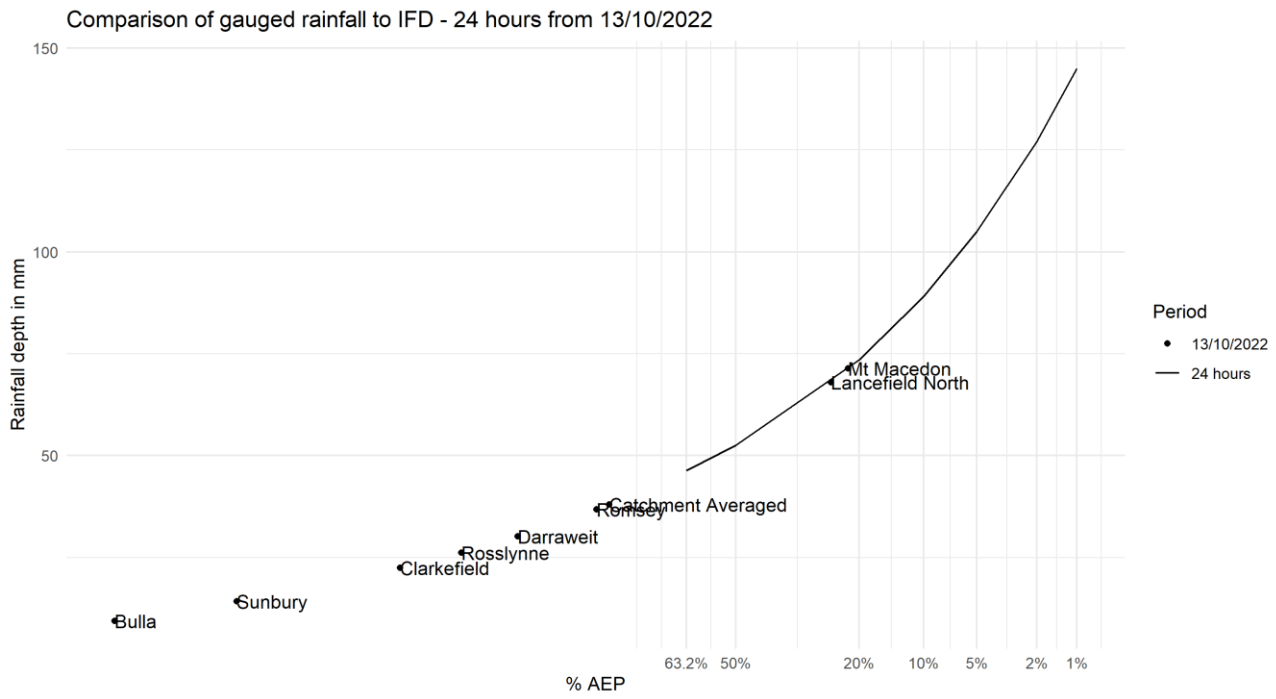



**Figure 3: Comparison of rainfall to 9:00am on the 13/10/2022 to catchment centroid IFD**

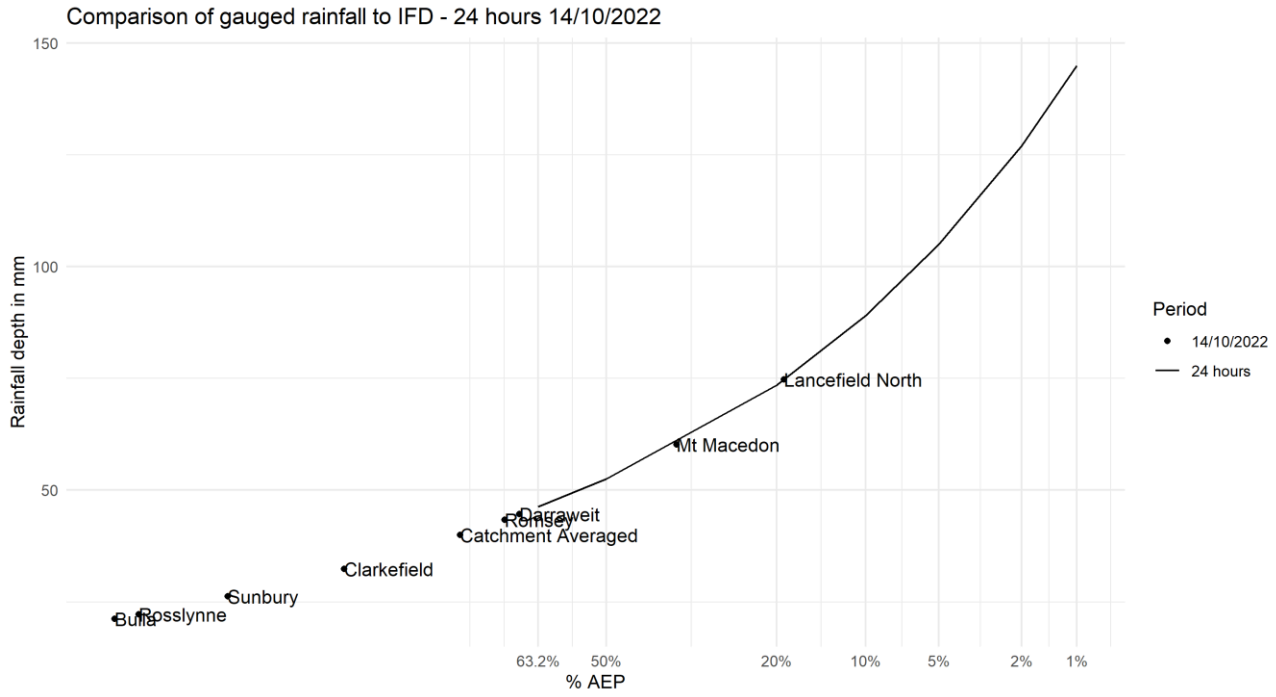



**Figure 4: Comparison of rainfall to 9:00am on the 14/10/2022 to catchment centroid IFD**

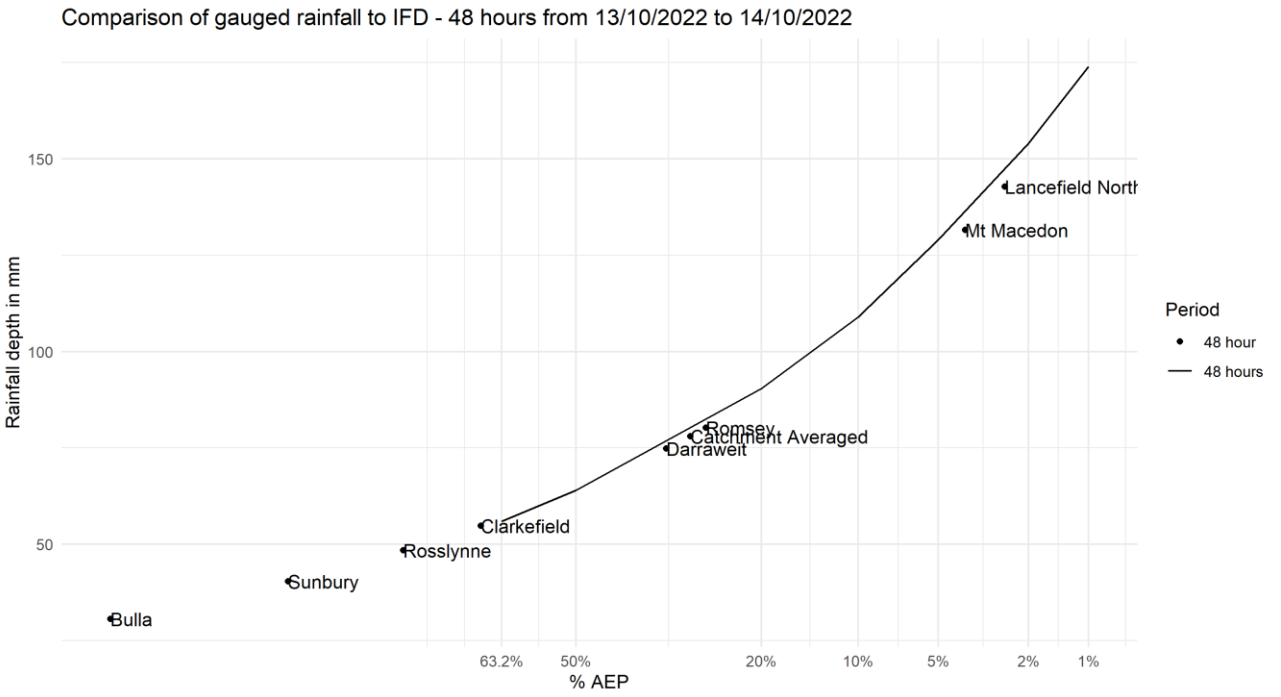



**Figure 5: Comparison of 48 rainfall on the 13/10/2022 and 14/10/2022 to catchment centroid IFD**

The spatial distribution of rainfall totals received across the catchment can be seen in Silo daily rainfall data[19] [accessed on 24/10/22] as shown in Figure 6, Figure 7 and Figure 8. These figures show that the highest rainfall fell in the upper portion of the catchment on the 13th and14th October 2022. The Silo data was used to calculate the observed catchment average rainfall for the 13th and 14th October 2022 as listed in Table 2, together with the estimated AEP of the rainfall event based on the Intensity Duration Frequency for the catchment centroid information obtained from the Bureau[20] (2022). Table 2 indicates that the observed catchment average rainfall for the event was relatively modest, with a 48-hour AEP of between 50% (1 in 2) to 20% (1 in 5).

It should be noted that that the catchment averaged rainfall has not been corrected using the factors in Durrant and Bowman (2004), which would increase the rainfall. Conversely, the catchment centroid IFDs should be discounted by the Areal Reduction Factors, which for the Maribyrnong is approximately 0.9. Applying these two corrections does not affect the AEPs listed in Table 2.

**Table 2: Observed catchment average rainfall depths for 13th and 14th October 2022**

| | 13th October 2022 | 14th October 2022 | 13th & 14th October 2022 combined in mm |
|---|---|---|---|
| Rainfall | 38mm | 40mm | 78mm |
| Estimated AEP | < 62.3% AEP | 62.3% AEP | 50% to 20% AEP |

The information in Table 1 agrees with the distribution of rainfall shown in Figure 6, Figure 7 and Figure 8; with both data sources demonstrating that there were higher rainfall totals in the upper catchment.

[19] Silo Australian climate data [accessed at https://www.longpaddock.qld.gov.au/silo/ on 24/10/22]

[20] http://www.bom.gov.au/water/designRainfalls/revised-ifd/ [accessed 16/10/22]

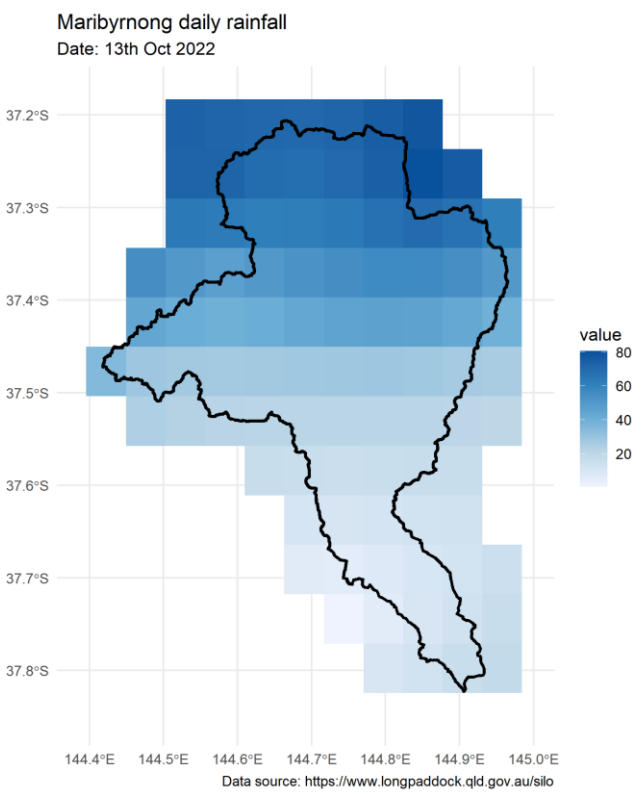



**Figure 6: Maribyrnong catchment rainfall 13th October 2022**

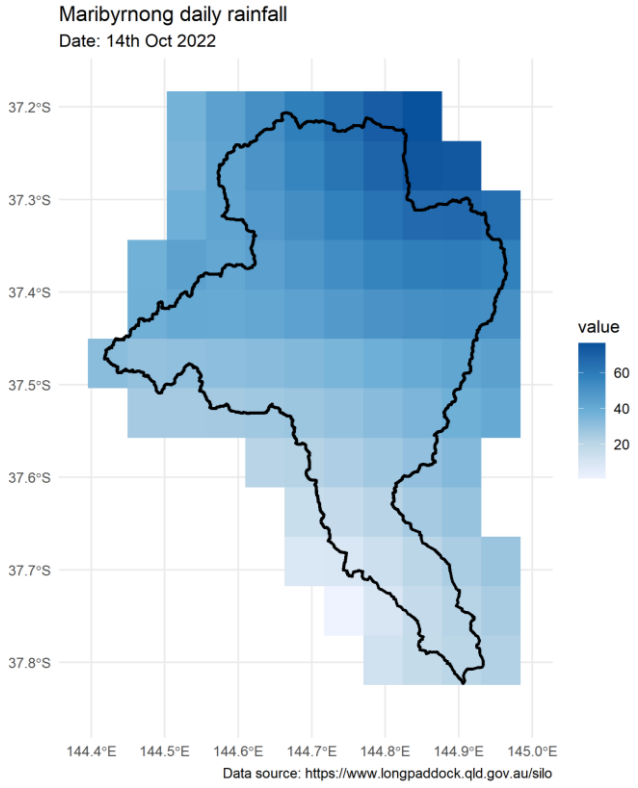



**Figure 7: Maribyrnong catchment rainfall 14th October 2022**

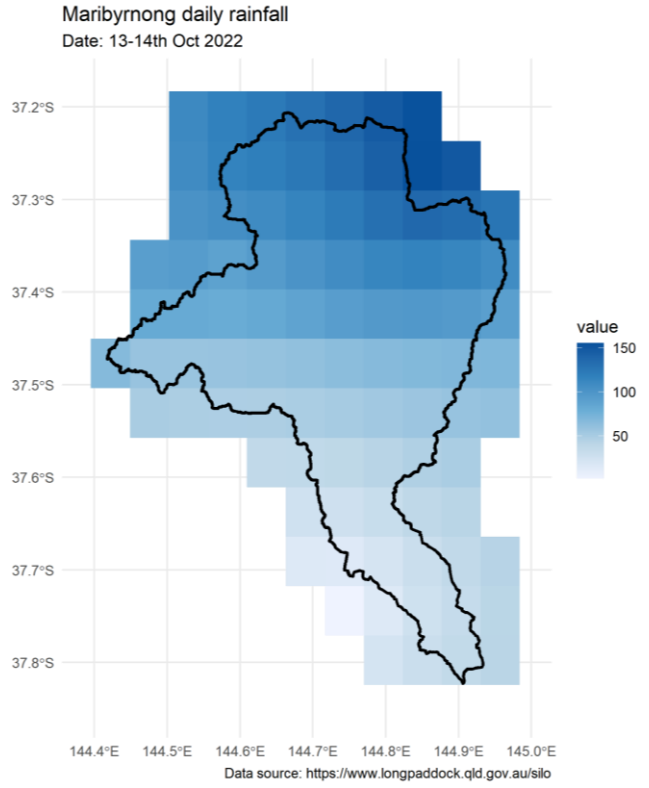



**Figure 8: Maribyrnong catchment rainfall 13th & 14th October 2022**

## Bureau of Meteorology October 2022 Rainfall Analysis

Analysis completed by the Bureau of Meteorology[21] for October 2022 has shown that the month's rainfall was significantly above average across most of Victoria (Figure 9), including large areas of highest on record for October (Figure 10). For Victoria overall, it was the highest monthly rainfall recorded since records began in 1900.

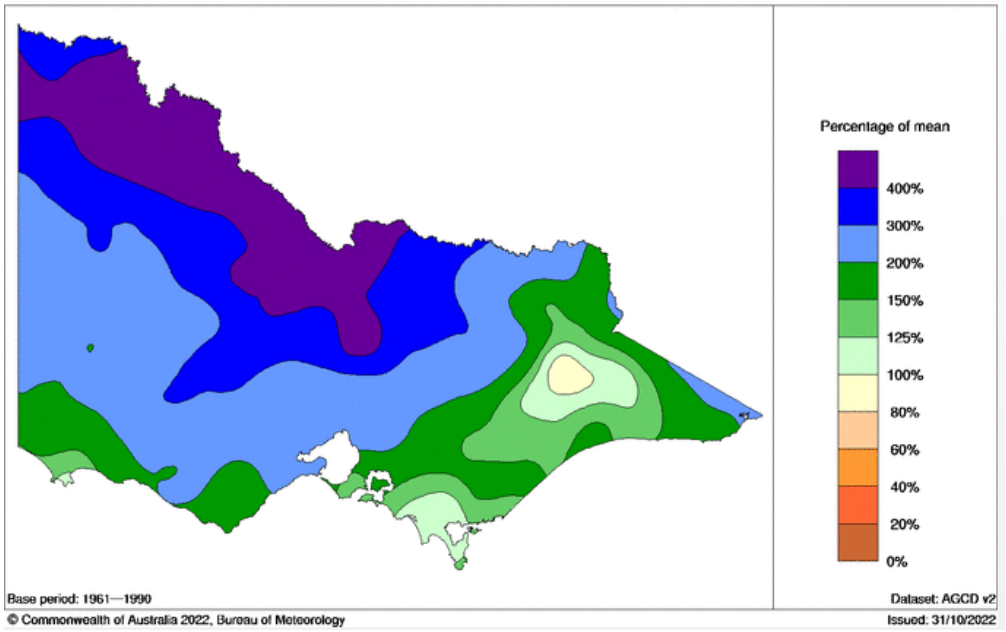



**Figure 9: October 2022 recorded rainfall for Victoria, shown as a percentage of the mean October rainfall for period from 1961 – 1990 (The Bureau, 2022[21])**

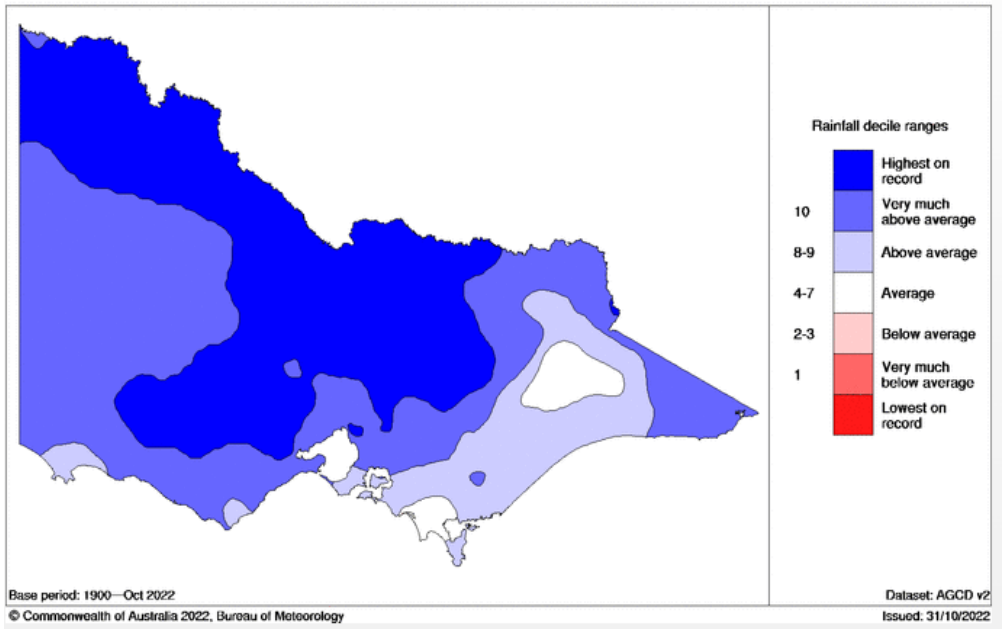



**Figure 10: October 2022 recorded monthly rainfall across Victoria, shown as decile ranges for October for the period from 1900 to 2022. (The Bureau, 2022[21])**

[21] The Bureau, 2022. Victoria in October 2022: wettest month on record, very warm nights [accessed at: http://www.bom.gov.au/climate/current/month/vic/summary.shtml on 10/11/22].

# Antecedent conditions

Antecedent conditions, or the wetness of the catchment prior to the rainfall event, can have a significant impact on the magnitude of the resultant flood event. A good proxy for antecedent catchment conditions is the rainfall that has fallen in the catchment prior to the actual flood event and the preceding days' streamflow.

## Rainfall

Rainfall totals for gauges in the Maribyrnong River catchment were acquired from Silo[15] [accessed 13/11/2022] and compared to long-term average and maximum rainfalls at selected Maribyrnong catchment gauges. Table 3 compares the September 2022 recorded rainfalls to the September long-term statistics and compares the recorded data for 1st to 12th October 2022 to the October long-term statistics.

In general, the Maribyrnong catchment experienced wetter than usual conditions prior the storm event on 13-14th October 2022. The total rainfall in September 2022 was higher than the mean at all selected gauges. For instance, Lancefield station (87173) had the highest above average rainfall for September (+74% higher than the average 70.7 mm). Between the 1st and the 12th of October 2022, a number of the gauges were close to receiving their mean monthly rainfall, demonstrating wetter than usual conditions in the catchment prior to the storm event on 13-14th October 2022. The majority of this rainfall fell during a storm event that occurred between 6th and the 8th of October 2022, the totals of which are detailed in Table 4. These observations of wetter than usual conditions are confirmed in the Bureau's analysis of rainfall preceding the event in the week up to the 13th October 2022 (Figure 11).

**Table 3: Recent and monthly rainfall totals for September at selected gauges in Maribyrnong catchment compared to monthly statistics. Mean and max are based on period from 1990 to 2022[22].**

| Station (no.) | September mean (mm) | September max (mm) | September 2022 (mm) | September 2022 % difference from September mean |
|---|---|---|---|---|
| Lancefield (87173) | 70.7 | 209.0 | 116.0 | +64% |
| Sunbury (87061) | 49.9 | 142.0 | 63.3 | +27% |
| Macedon (87036) | 76.8 | 248.0 | 106.0 | +38% |
| Romsey (87130) | 68.1 | 185.0 | 97.4 | +42% |
| Melbourne Airport (86282) | 46.6 | 127.0 | 49.0 | +5% |
| Silo Catchment Average | 72.0 | 333.0 | 100.0 | +39% |

[22] All stations with the exception of Melbourne Airport contained missing data which was infilled through interpolation as outlined in Jeffery et al. (2001). For Lancefield interpolated data was used from 01/01/1990 to 01/04/1993.

Jeffrey, S.J., Carter, J.O., Moodie, K.B. and Beswick, A.R. (2001). *Using spatial interpolation to construct a comprehensive archive of Australian climate data*, Environmental Modelling and Software, Vol 16/4, pp 309-330. DOI: 10.1016/S1364-8152(01)00008-1.

**Table 4: Recent and monthly rainfall total for October at selected gauges in Maribyrnong catchment compared to monthly statistics.**

| Station (no.) | October mean (mm) | October max (mm) | 1st - 12th October 2022 (mm) | Storm event 6th - 8th October 2022 (mm) |
|---|---|---|---|---|
| Lancefield (87173) | 60.6 | 238.0 | 44.8 | 38.2 |
| Sunbury (87061) | 54.6 | 152.0 | 42.1 | 38.2 |
| Macedon (87036) | 68.3 | 196.0 | 68.6 | 36.0 |
| Romsey (87130) | 61.8 | 217.0 | 48.2 | 38.2 |
| Melbourne Airport (86282) | 54.5 | 151.0 | 50.0 | 47.4 |
| Silo Catchment Average | 70.0 | 204.0 | - | - |

Table 3 and Table 4 also include the Maribyrnong catchment average rainfall in the months of September and October acquired from Silo rainfall data[15]. Agreement is evident between the mean rainfall information from Silo and gauge data records.

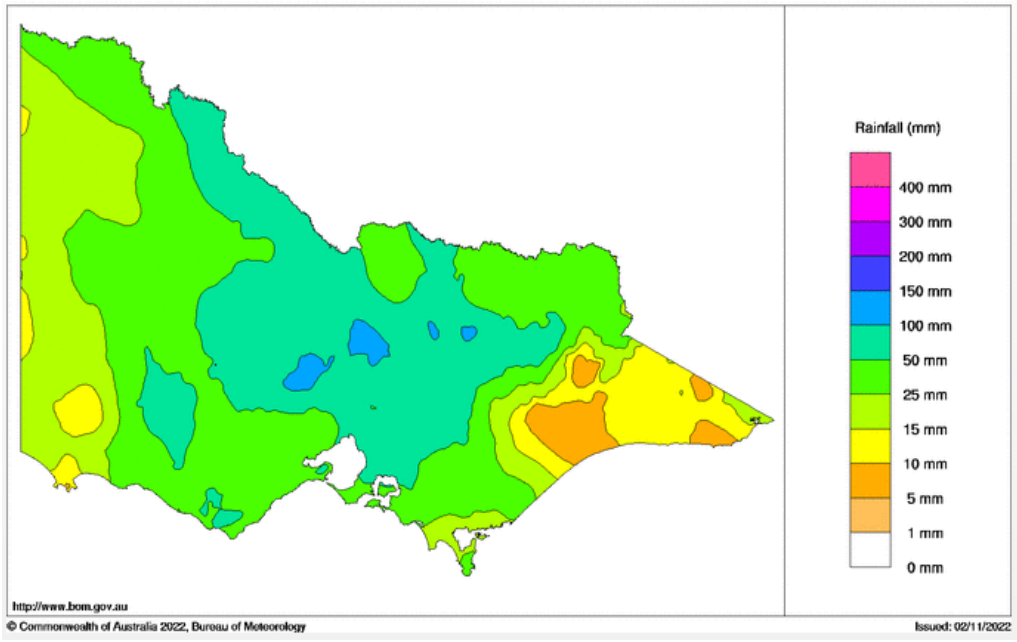



**Figure 11: Total rainfall for Victoria over period from 07th October to 13th October 2022. (The Bureau, 2022[21])**

## Streamflow

Antecedent conditions can also be assessed through review of the streamflow preceding the event. Analyses of the average daily flow on the 12/10/2022 indicated that the discharge occurred on less than 4% of days since 1990, demonstrating that the catchment was unusually wet prior to the flood event.

# River conditions

River conditions data were obtained from the Bureau of Meteorology and the Victorian Water Monitoring Site for a variety of sites in the Maribyrnong catchment, namely:

- Deep Creek at Darraweit Guim (230100A) – Discharge and stage
- Deep Creek at Konagaderra (230107A) – Discharge
- Bolinda Creek at Lancefield Road Clarkefield (230211A) – Discharge
- Deep Creek Downstream Bulla Road Bulla (230102A) - Discharge
- Jacksons Creek at Sunbury Road Sunbury (230104A) – Discharge
- Maribyrnong River at Keilor (230105A) – Discharge and stage
- Maribyrnong River at Maribyrnong – Discharge and stage

The October 2022 event for these gauges was plotted in Figure 12 and schematic location of these is shown in Figure 13.

Review of the information in Table 5, Figure 12 and Figure 13 shows that:

- There was a large flow event in the Deep Creek catchment.
- The Jacksons Creek catchments provided the next largest input in terms of flow.
- Although the Bolinda Creek / Emu Creek is only (approximately) 55% the size of the Jacksons Creek catchment, it provided a similar input in terms of flow.
- The gauge at Deep Creek Downstream Bulla Road Bulla is understood to have recorded the peak flow correctly, before failing and becoming inaccurate shortly afterwards, as is evident from the drop data values in Figure 12.

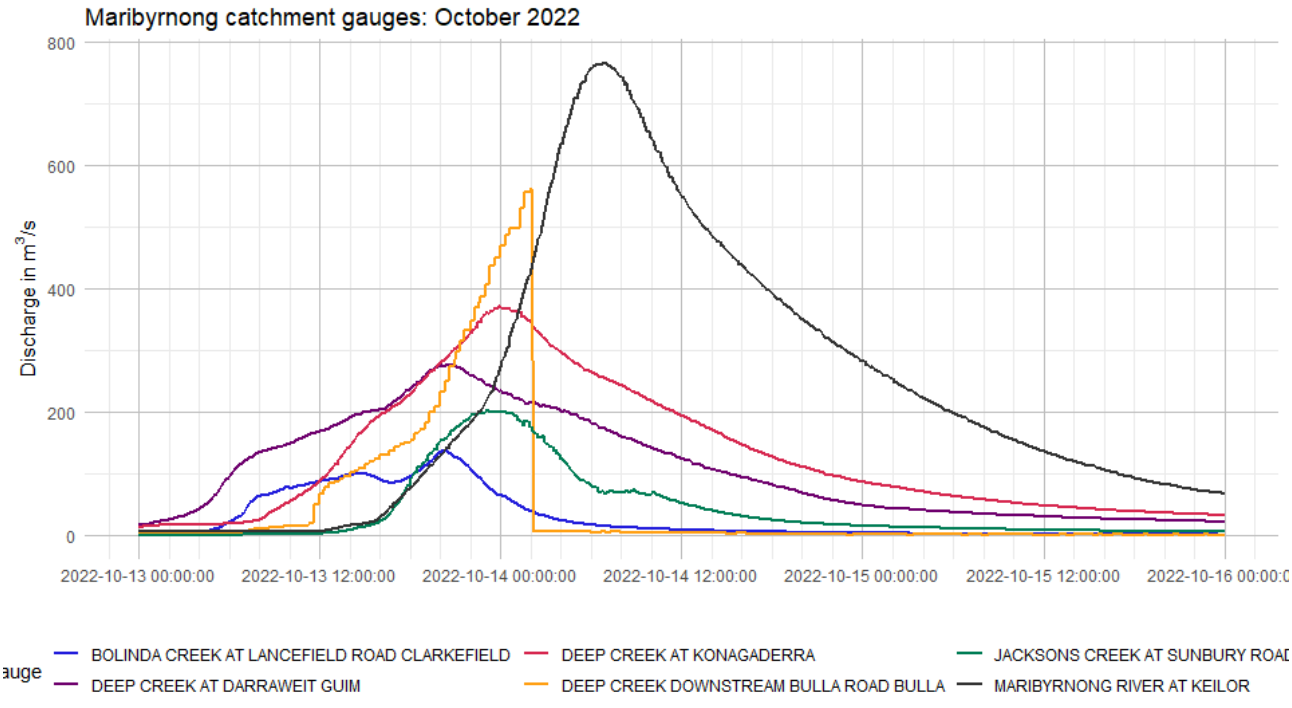



**Figure 12: Hydrographs for various gauges in the Maribyrnong catchment for the October 2022 event**

In addition to the gauged data, the Maribyrnong River at Keilor gauging station was visited on 01/11/2022. During this site visit flood debris was clearly visible at elevations that exceeded the maximum gauge board stage of 6.9 m. This is illustrated in Photo 1.

**Table 5: Peak flow rates and stages at various gauges in the Maribyrnong catchment**

| Site | Catchment area ($km^2$) | Record length* | Peak discharge ($m^3/s$) | Peak Stage (m) | Date of peak | Source |
|---|---|---|---|---|---|---|
| Jacksons Creek at Sunbury | 337 | 4/09/1975 – current* | 204 | NA | 14/10/2022 | Melbourne Water Rainfall and River Level |
| Deep Creek at Darraweit Guim | 500 | 5/09/1975 – current* | 280 | 7.22 | 13/10/2022 | The Bureau of Meteorology River and rainfall conditions |
| Deep Creek at Bulla Downstream of Emu Crk | 865 | 21/06/1955 - current | 98[1,2] | NA | 14/10/2022 | Victorian Water Monitoring |
| Maribyrnong River Downstream Jacksons Creek Keilor Nth | | 9/02/1998 – current* | 473[3] | NA | 14/10/2022 | Melbourne Water Rainfall and River Level |
| Maribyrnong River at Keilor | 1,303 | 4/09/1975 – current* | 768[4] | 8.64 | 14/10/2022 | Rainfall and River Level<br>Victorian Water Monitoring |
| Maribyrnong River at Maribyrnong | | 4/09/1975 – current* | 770 | 4.22 | 14/10/2022 | Stage - The Bureau of Meteorology River and rainfall conditions<br>Flow - Melbourne Water Rainfall and Rive Level |

* Record length based on Melbourne Water records; longer records exist in the DELWP database and have been used here in some instances.

[1] Rating table exceeded

[2] Stage trace shows signs of instability

[3] Potentially underestimated

[4] This was originally recorded as 827 before being revised to 768

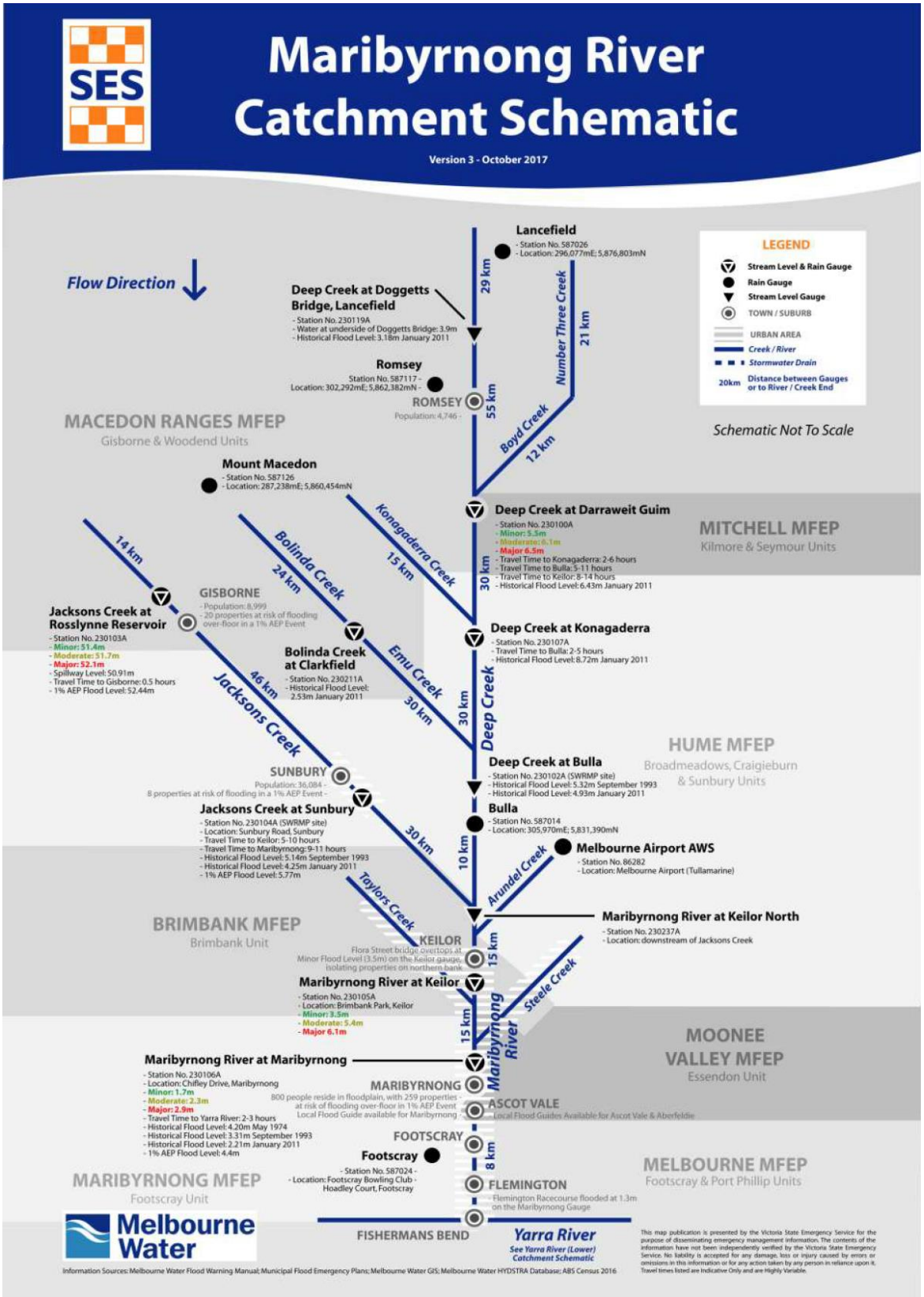



**Figure 13: Maribyrnong catchment schematic (from SES[23], 2018)**

[23] SES, 2018. City of Maribyrnong Storm and Flood Emergency Plan – A Sub-Plan of the MEMPlan – Version 4.0.

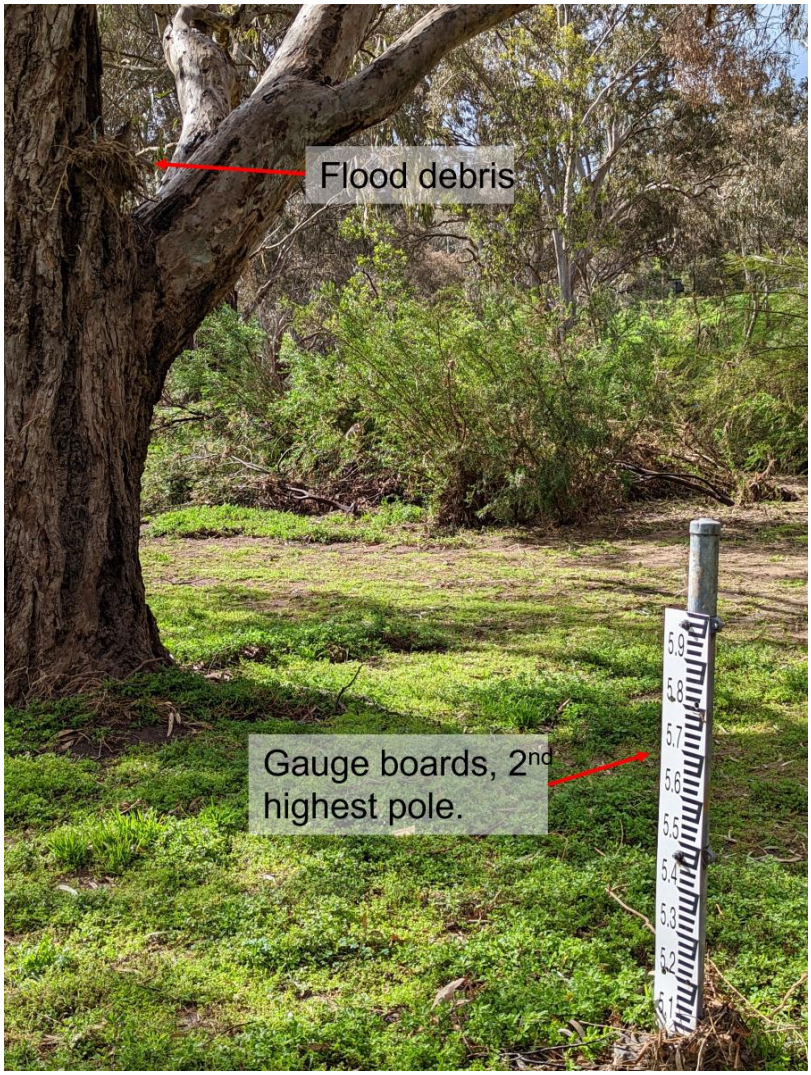



**Photo 1: Maribyrnong River at Keilor gauge – showing flood debris compared to gauge boards**

## Historical stages

The historical stages at the key gauges for at risk communities have been reviewed. These gauges were:

- Deep Creek at Darraweit Guim as the closest gauge to Darraweit Guim, with records dating back to 1975.
- Maribyrnong River at Keilor as the gauge with the longest record in the catchment and the most relevant for communities in Avondale Heights, Sunshine North, Braybrook, Maidstone, Essendon West, Maribyrnong, Aberfeldie, Ascot Vale, Footscray and Kennington.
- Maribyrnong River at Maribyrnong and the most relevant for communities in Aberfeldie, Ascot Vale, Footscray and Kennington.

## Deep Creek at Darraweit Guim

Stage data for Deep Creek at Darraweit Guim (230100A) was obtained from the Bureau of Meteorology Water Data Online website and the annual maxima stage series was extracted from gauged data (Figure 14). The catchment area to this gauge is approximately 500 $km^2$ and the highest stage at this gauge was 7.22 m, recorded during the recent October 2022 event. This stage is the highest since records began at this location in 1975, and the only event on record to exceed the major flood class level. The second highest stage was 6.43 m in 2011, just below the major flood class level, when significant flood damage was reported in the area[10, 11].

Data from an additional gauge (230208) located approximately 3 km upstream of gauge 230100A was also available from the Bureau of Meteorology Water Data Online website (period of record: 1975 – 1994). The catchment area to this gauge is approximately 350 $km^2$. A review of this data found inconsistencies in the gauged stages and flows recorded at the two locations, which are expected due to the presence of a tributary (Boyd Creek, catchment area approx. 150 $km^2$) flowing into Deep Creek between the two sites. A significant flow event with a peak of 537 $m^3/s$ was recorded only at the 230208 gauge in 1975 (almost double the peak flow of the October 2022 event, 280 $m^3/s$). Confidence in this 1975 flow estimate at the 230208 gauge is low due to the following:

- Stage data for the same gauge (230208) does not indicate a high flow event of this magnitude occurred on this date (peak stage: 5.18 m). It is possible that the rating curve for the gauge is of low quality for these stages.
- There is no evidence of a high flow event of a similar magnitude from a review of gauged records upstream and downstream along Deep Creek or the Maribyrnong River.
- There are no records of reported flooding in media reports for 1975.
- For these reasons, the 1975 537 $m^3/s$ event was discounted from the analysis.
- There is no data available from the 230100A gauge for this date.

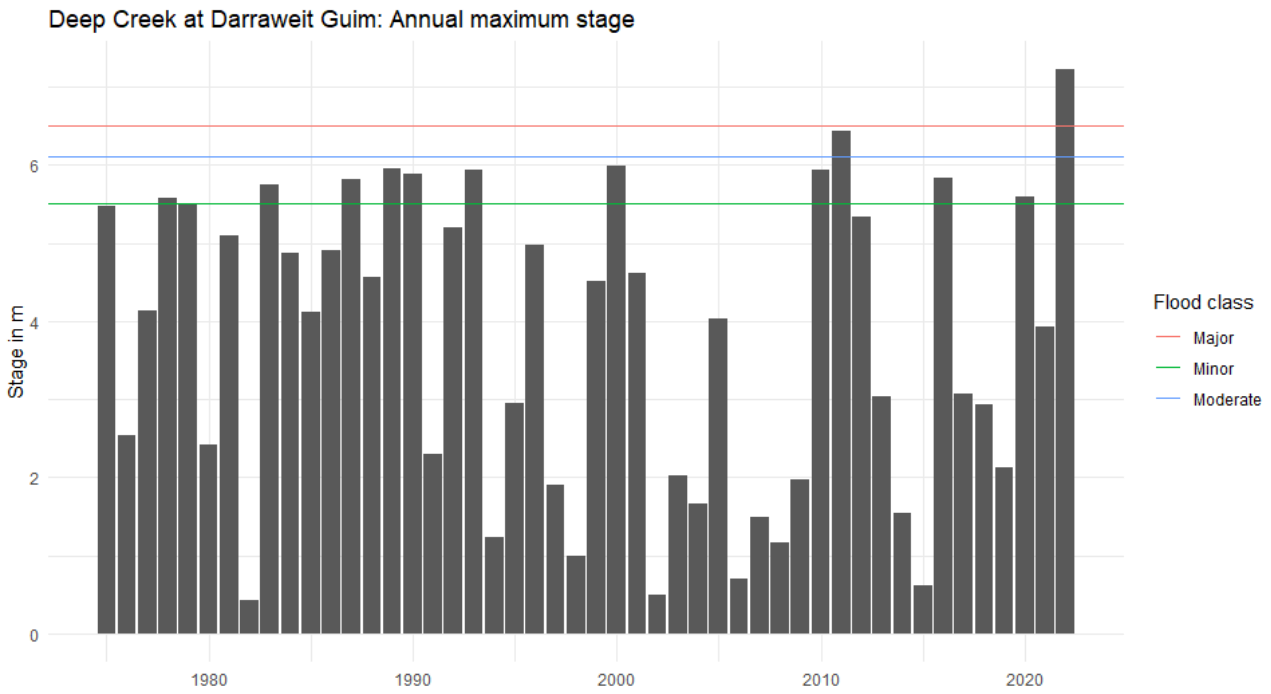



**Figure 14: Deep Creek at Darraweit Guim – annual maximum stage data (1975 – 2022) (The Bureau[5], 2022)**

## Maribyrnong River at Keilor

Review of the stage data for the Maribyrnong River at Keilor obtained from the Victorian Water Monitoring Site indicated that the gauge has moved, as evidenced in the "Blue Books"[24], and direct comparison may not be possible to earlier records. Significant flood events were extracted from gauged data[25] from 1974 (Figure 15) at a consistent gauge location. The highest stage prior to the October 2022 event was 7.25 m (1974), followed by 6.84 m (1993). These compare to a stage of 8.64 m from the October 2022 event. This indicated that the recent event is the largest since gauging started at this location in 1974.

[24] Rural Water Commission of Victoria (1987) Victorian Surface Water Information to 1987, Volume 2, Drainage Division II River Basin 29-39.

[25] DEWLP Maribyrnong at Keilor continuous streamflow data (1908 – present) [accessed at data.water.vic.gov.au on 3/11/22]

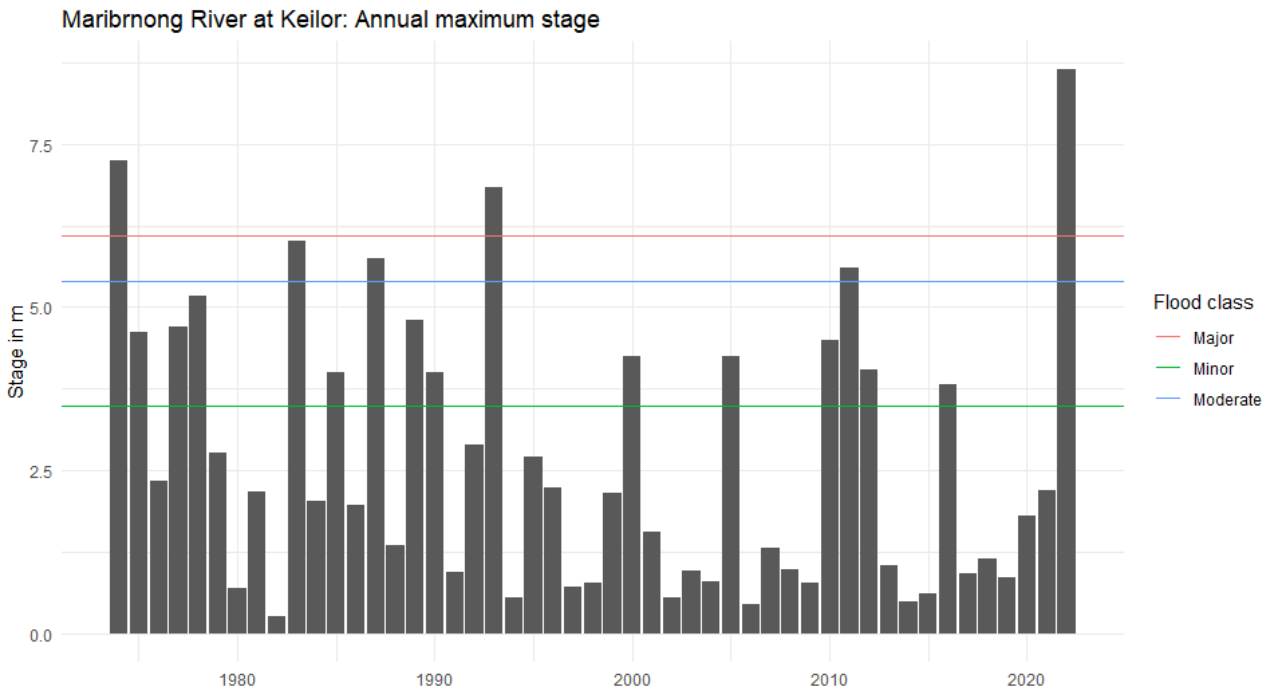



**Figure 15: Maribyrnong River at Keilor – annual maximum stage data (1974 – 2022) (DEWLP[25], 2022)**

## Maribyrnong River at Maribyrnong

The stage data for the Maribyrnong River at Maribyrnong is considered to be consistent and this has been verified through a number of sources (SES[23], 2018; MMBW[12], 1986). The table of the Maribyrnong River at Maribyrnong water stages from the SES (2018) stages is shown in Figure 1. This information shows that the recent event is the 3rd highest, slightly more than the 1974 event. It is noted the 1916 event (rank 2) was 40 mm higher than the October 2022 event, however there is uncertainty associated with historic records due to catchment changes and the passage of time. Overall, the October 2022 event is considered to be the 2nd largest in flow.

Review of available gauge records for the Maribyrnong River at Maribyrnong has highlighted some inconsistencies between the peak flow and peak stage recorded for older flood events, namely the 1916 event. With regards to the Maribyrnong River at Keilor, the peak stage recorded in 1916 was 2nd highest, whereas the peak flow recorded was only 5th highest. This inconsistency can be explained by:

- Changes in upstream catchment conditions (from forested/rural conditions to more urbanised land use)
- The presence of low-lying infrastructure and a heavily developed floodplain in the early part of the twentieth century in the Maribyrnong Township floodplain has been noted by historic newspaper reports[26], which would have locally increased flood levels.
- Considerable uncertainty in the historic methods used to record levels and calculate flows.

## Annual exceedance probability

The annual exceedance probability was calculated for the streamflow gauges closest to as risk communities that were considered to be most suitable. These were:

[26] https://trove.nla.gov.au/newspaper/article/74594281?searchTerm=flood%20maribyrnong [accessed 20/12/2022]

- Deep Creek at Darraweit Guim for Darraweit Guim
- Maribyrnong River at Keilor Gauge for Maribyrnong Township and the lower Maribyrnong area

While the Maribyrnong River at Maribyrnong is closer to Maribyrnong Township it is not suitable for this type of analysis for the following reasons:

- The gauge is tidally influenced
- There was a change from chart datum to meters Australian Height Datum (AHD) in 2008
- The record length at Keilor is significantly longer
- The MMBW (1986) report concluded that "*it reasonable to assume that the flows measured at Keilor are equivalent to flows at the Maribyrnong Township*."

## Deep Creek at Darraweit Guim

An at-site Flood Frequency Analysis (FFA) for Deep Creek at Darraweit Guim was undertaken using an annual maxima series including peak flow estimates for the recent event in October 2022. The resulting flood quantiles are given in Table 6. Technical details of the FFA can be found in Appendix A.

**According to the FFA, the Deep Creek at Darraweit Guim peak flow rate was 280 $m^3/s$, which is close to a 1% AEP (300 $m^3/s$) event.**

**Table 6: Deep Creek at Darraweit Guim FFA results.**

| AEP | FFA Expected Quantile ($m^3/s$) |
|---|---|
| 20% | 120 |
| 10% | 160 |
| 5% | 200 |
| 2% | 255 |
| 1% | 300 |

## Maribyrnong River at Keilor

An updated at-site Flood Frequency Analysis (FFA) for the Maribyrnong River at Keilor Gauge was undertaken using an annual maxima series including a peak flow estimates for the recent event in October 2022. These results were compared to the flood quantiles estimated by the MMBW (1986) Maribyrnong River Flood Mitigation Study[12]. Technical details of the FFA are presented in Appendix A and the resulting flood quantiles presented in Table 7.

**According to the updated FFA, the Maribyrnong River at Keilor peak flow rate was 768 $m^3/s$, which is just above a 2% AEP (760 $m^3/s$) event.**

**Table 7: Comparison of current Maribyrnong River at Keilor FFA results with previous MMBW (1986) estimates.**

| AEP | MMBW (1986) FFA Quantile ($m^3/s$) | Current FFA Expected Quantile ($m^3/s$) | % Change |
|---|---|---|---|
| 20% | 270 | 285 | +6% |
| 10% | 400 | 420 | +5% |
| 5% | 530 | 565 | +7% |
| 2% | 710 | 760 | +7% |

| AEP | MMBW (1986) FFA Quantile ($m^3/s$) | Current FFA Expected Quantile ($m^3/s$) | % Change |
|---|---|---|---|
| 1% | 840 | 915 | +9% |

The updated FFA results were compared to the flood quantiles estimated by MMBW (1986), as presented in Table 7. The estimates produced from the current study are greater than those from the previous work by between 5-9%. This due to:

1. The additional 40 plus years of data
2. More sophisticated analysis techniques
   a) A Bayesian approach verses a method of moment approach
   b) The ability to safely censor low flows
   c) The incorporation of historic information

This increase in the discharge for flood quantiles can be intuitively explained by considering the occurrence of major flood events since 1986. In the period 1871 to 1986, 115 years, there were two observed peak flows in excess of 650 $m^3/s$ (1908 - rank 1 and 1974 - rank 3). In the period since (36 years) there have been an additional two events greater than 650 $m^3/s$ (1993 - rank 4 and 2022 - rank 2). The FFA results from the current study are therefore considered reasonable, in alignment with expectations and observed/reviewed data.

The MMBW (1986) Maribyrnong River Flood Mitigation Study[12] completed a frequency analysis along the Maribyrnong River. The flows at Keilor were based on gauge data available at the time. The Maribyrnong (230106) flows were assumed to have the same peak flows as Keilor based on the following:

- It was concluded there is little inflow between the Maribyrnong and Keilor gauge.
- The Maribyrnong gauge is influenced by tidal conditions.
- The catchment is long and narrow between the two locations.

# Observations compared to 1% Flood Map

The DEWLP 1% (1 in 100) AEP flood extent spatial layer (DELWP[27]) was obtained from the DELWP site [accessed on 9/11/2022] and compared to known flooding and terrestrial photography at a variety of locations. The DEWLP 1% AEP flood extent layer was used for comparison purposes in this exercise, as the 2% (1 in 50) AEP was not publicly available. These have been grouped as follows:

- Deep Creek at Darraweit Guim (Figure 16)
- Canning Street Bridge (Figure 17)
- Affon Street and Aberfeldie Park (Figure 18)
- Kensington area - Maribyrnong River Viaduct and Rail Bridge (Figure 19)

## Deep Creek at Darraweit Guim

Comparison of the DEWLP 1% AEP flood extent data (Figure 16) to observations of flooding noted at Darraweit Guim shows following:

- Darraweit Guim Primary School was reported as being inundated in the October 2022 event[1]. The School is shown as being located within the 1% AEP flood extent.
- Few other properties are shown to be within the 1% AEP flood extent, however a review of this data suggests it is of low quality at this location and will therefore have associated uncertainties.

## Canning Street Bridge

Comparison of the 1% AEP flood extent to photos in and around the Canning Street Bridge area shows that the flood extent was near, but slightly less than the 1% AEP extent as shown in Figure 17. Specifically:

- Upstream of Canning Street Bridge – the 1% AEP extent was consistent with the observed flooding although it is noted that it was difficult to be precise with available data.
    - The 1% AEP extent shows inundation in and around Blueridge Close and Evergreen Avenue in Figure 17. It was observed that this area had been flooded and did not appear to be as extensive as the flood mapping indicated, although a full inspection of the area was not undertaken.
- Downstream of Canning Street Bridge - the 1% AEP extent was consistent with the observed flooding although it is noted that it was difficult to be precise with available data.
- Canning Street Reserve – the flood extents are close to the mapped 1% AEP extents noting that a) the photo was taken after the peak estimated to be around 100mm higher; and b) the floodplain in this location was relatively steep.
- Tea Garden Reserve – the 1% AEP extent was consistent with the observed flooding although it is noted that it was difficult to be precise with available data.

## Affon Street and Aberfeldie Park

Comparison of the 1% AEP flood extent to photos in and around the Affon Street and Aberfeldie Park areas shows that the flood extents were slightly less than the 1% AEP extent as shown in Figure 18. Specifically:

- The Old Defence Site – The 1% AEP extent does not show the levees around the old defence site overtopped but does show inundation behind the levee. The mechanism for the inundation behind

[27] DEWLP, 2020 '1 in 100 year flood extent' [accessed at https://discover.data.vic.gov.au/dataset/statistical-extents-for-1-aep-or-1-in-100-years-floods-until-2014 on 9/11/22]; referred to in the text at the 'DEWLP 1% AEP flood extent layer'.

the levee in the DELWP mapping is not clear. Photos of this area show no inundation behind the levee and water against the levee. This suggests that the flood extent was close to, but less than the 1% AEP flood.

- Affon Street – Photos of the carpark and along Affon Street show the flood extents were slightly less than the 1% AEP (taking into account that the photos were taken slightly after the peak). The mapped extent covers the speed bump on Affon Street near The Boulevard, whereas the observed flood extent stopped just short of this.
- The Boulevard – Photos taken along The Boulevard and carpark show that the flood extents were slightly less than the 1% AEP (taking into account that the photos were taken slightly after the peak).
- Chifley Drive – Photos taken across from The Boulevard across the river to Chifley Drive indicate that the flood extents were less than the 1% AEP.
- Aberfeldie Park – Photos of Aberfeldie Park are generally in agreement with the 1% AEP flood extents, although given the relatively steep floodplain it was difficult to be precise with available data.

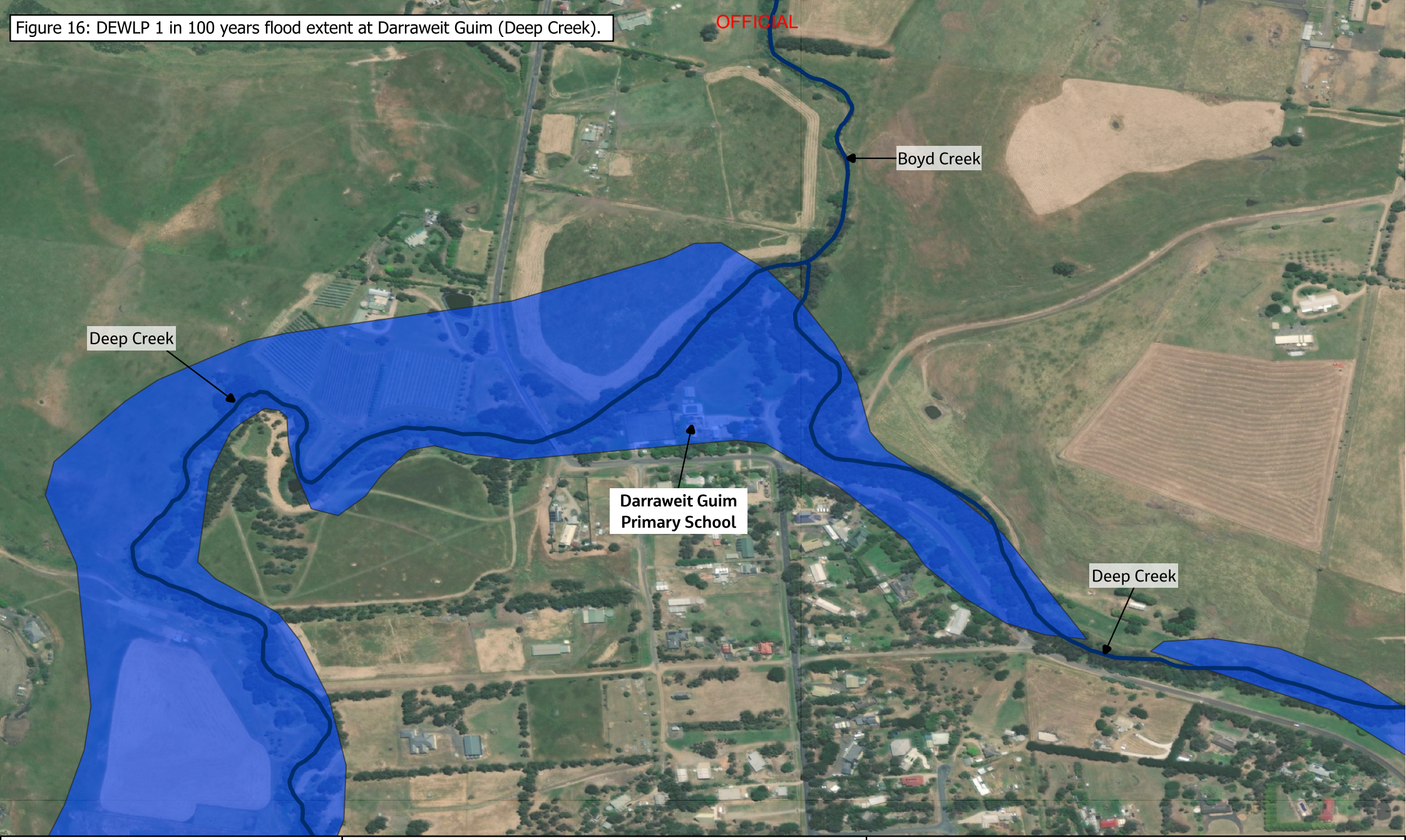
## Maribyrnong River – Kensington area

Comparison of the 1% AEP flood extent to photos of the Maribyrnong River around the Kensington area shows that the flood extent was close to, but below the 1% AEP extent as shown in Figure 19. Specifically:

- Princes Highway – photos taken from the footpath indicate the flood extent was slightly less than the 1% AEP (taking into account that the photos were taken slightly before the peak).
- Riverside Park – the 1% AEP extent is inconsistent with the observed flooding that occurred. Photos taken show widespread inundation at Riverside Park, whereas the park is dry in the DEWLP 1% AEP extent.
- Crescent Street – the 1% AEP extent is inconsistent with the observed flooding that occurred. Photos taken show inundation of Crescent Street, whereas this area is dry in the DEWLP 1% AEP extent. This is likely due to underground drainage not being used in the modelling that the DEWLP 1% AEP extent was derived from.
- Newells Paddock Wetland Reserve – Photos are generally in agreement with the 1% AEP flood extents, although it was difficult to be precise with available data.
- Kensington Rail Bridge – Photos are generally in agreement with the 1% AEP flood extents, although it was difficult to be precise with available data.
- Hobsons Road – Photos taken from Bateman Road looking on to Hobsons Road are generally in agreement with the 1% AEP flood extents (noting that photos were taken slightly after the peak).

Figure 16: DEWLP 1 in 100 years flood extent at Darraweit Guim (Deep Creek).






**Legend**

Watercourse

1 in100 years floods until 2014
Data Source: DELWP
Access Date: 9/11/2022
Aerial imagery: Bing Maps

MGA Zone 55

0 50 100 150 m

Jacobs

**Comparison of the 1 in100 years flood extent to flood photos**

Deep Creek at Darraweit Guim
1 in 100 year flood

Notes about this map: Photos shown were taken during the October 2022 flood event but were not necesarily taken at the peak of the event. This map should be viewed in conjuction with this report, and was intended for use by Melbourne Water technical staff.
DELWP data source: https://discover.data.vic.gov.au/dataset/statistical-extents-for-1-aep-or-1-in-100-years-floods-until-2014

Project Number:
IA5000LI

**Status: FINAL**


Figure 17: Comparison of the DEWLP 1 in 100 years flood extent to flood photos at Maribyrnong River - Canning St Bridge.

**Legend**

1 in 100 years floods until 2014
Data Source: DELWP
Access Date: 9/11/2022
Aerial imagery: Bing Maps

MGA Zone 55

0 100 200 300 m

Jacobs

**Comparison of the 1 in100 years flood extent to flood photos**

Maribyrnong River Flooding at Canning St Bridge
Peak in river occured at approximate 12-1pm on (14/10/2022)

Notes about this map: Photos shown were taken during the October 2022 flood event but were not necesarily taken at the peak of the event. This map should be viewed in conjuction with this report, and was intended for use by Melbourne Water technical staff.
DELWP data source: https://discover.data.vic.gov.au/dataset/statistical-extents-for-1-aep-or-1-in-100-years-floods-until-2014

Project Number:
IA5000LI

Status: FINAL

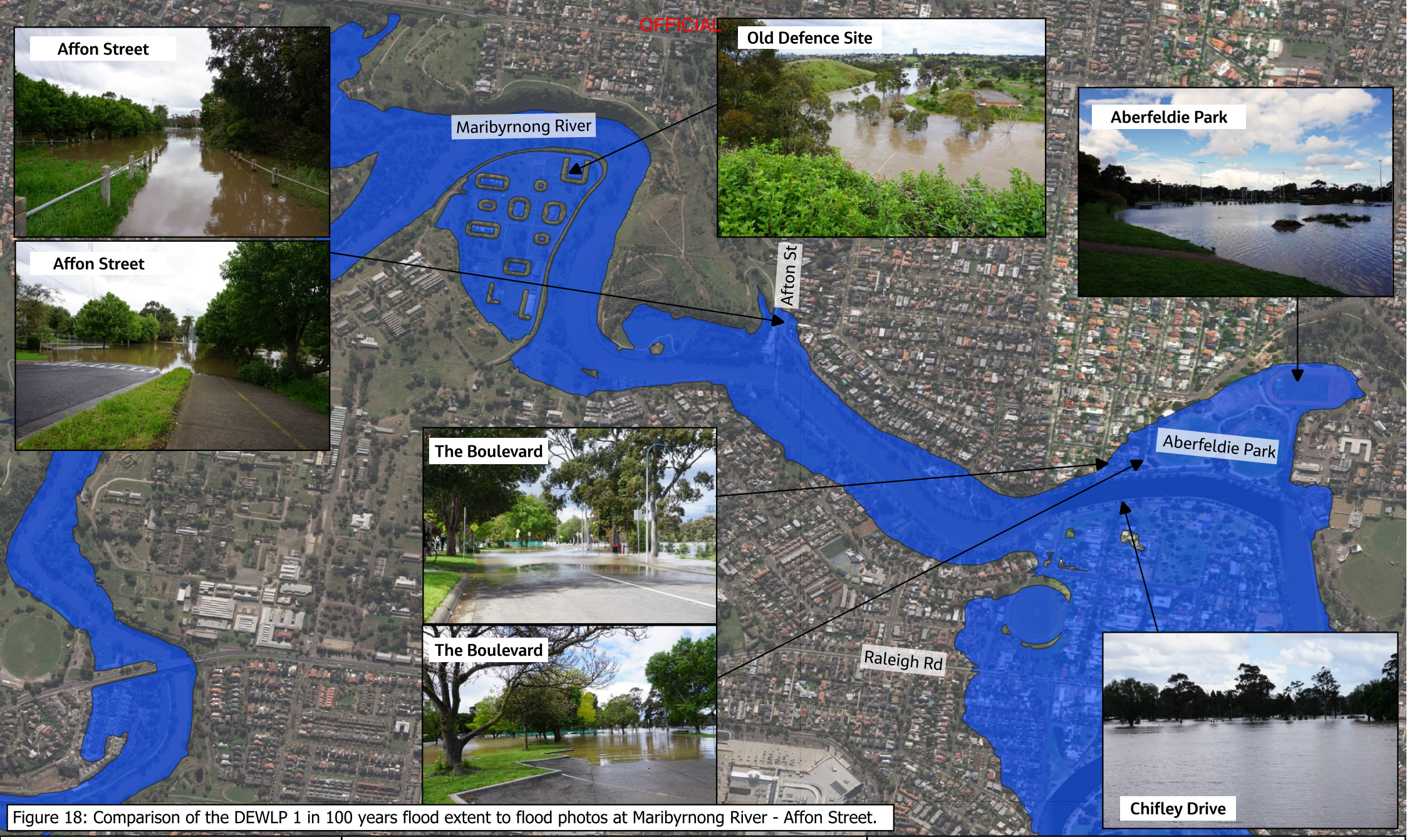



Figure 18: Comparison of the DEWLP 1 in 100 years flood extent to flood photos at Maribyrnong River - Affon Street.

**Legend**

1 in 100 years floods until 2014
Data Source: DELWP
Access Date: 9/11/2022
Aerial imagery: Bing Maps

MGA Zone 55

0 100 200 300 m

Jacobs

**Comparison of the 1 in100 years flood extent to flood photos**

Maribyrnong River Flooding at Affon Street
Peak in river occured at approximate 12-1pm on (14/10/2022)

Notes about this map: Photos shown were taken during the October 2022 flood event but were not necesarily taken at the peak of the event. This map should be viewed in conjuction with this report, and was intended for use by Melbourne Water technical staff.
DELWP data source: https://discover.data.vic.gov.au/dataset/statistical-extents-for-1-aep-or-1-in-100-years-floods-until-2014

Project Number:
IA5000LI

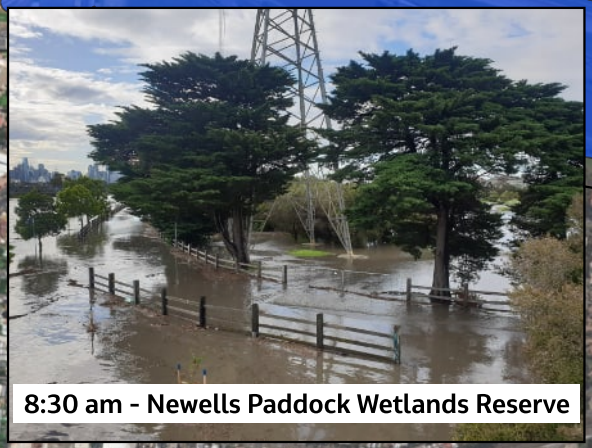
Status: FINAL

Figure 19: Comparison of the DEWLP 1 in 100 years flood extent to flood photos at Maribyrnong River - Kensington area.



8:30 am - Princes Highway

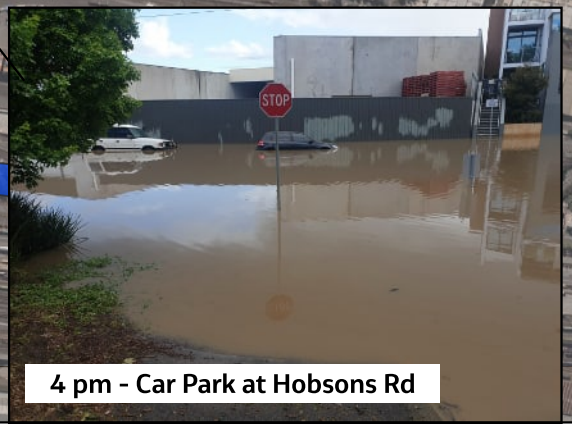
8:30 am - Riverside Park



8:30 am - Newells Paddock Wetlands Reserve

4 pm - The Crescent St

8:30 am - Kensington Railway Bridge



4 pm - Car Park at Hobsons Rd

Princes Hwy

Maribyrnong River

Kensington Bridge

Railway

## Legend

1 in 100 years floods until 2014
Data Source: DELWP
Access Date: 9/11/2022
Aerial imagery: Bing Maps

MGA Zone 55

0 100 200 300 m

Jacobs

**Comparison of the 1 in100 years flood extent to flood photos**

Maribyrnong River Flooding around Kensington area
Peak in river occured at approximate 12-1pm on (14/10/2022)

Notes about this map: Photos shown were taken during the October 2022 flood event but were not necesarily taken at the peak of the event. This map should be viewed in conjuction with this report, and was intended for use by Melbourne Water technical staff.
DELWP data source: https://discover.data.vic.gov.au/dataset/statistical-extents-for-1-aep-or-1-in-100-years-floods-until-2014

Project Number:
IA5000LI

Status: FINAL

# Conclusions

Flooding in the Maribyrnong River catchment on the 13th and 14th October 2022 followed significant rainfall across the catchment in the days preceding the event. A post-flood analysis for the Maribyrnong River catchment has been completed that considered rainfall, antecedent conditions and river conditions for the October 2022 flood event using publicly available information in October 2022 except where explicitly stated.

The analysis found that rainfall was modest in the lower parts of the Maribyrnong River catchment and had return periods approaching a 1-2% AEP in the upper catchment (the Deep Creek catchment). Review of river conditions found that Deep Creek at Darraweit Guim experienced a flood event approaching the 1% AEP, which was attenuated to approximately a 2% AEP at Keilor and around Maribyrnong Township. The Deep Creek catchment is the largest contributing catchment area to flows in the Maribyrnong River. The 13-14th October 2022 runoff response of the Maribyrnong River catchment was exacerbated by the wetter than usual antecedent conditions, including a 30-40mm storm across the catchment on the 6th-8th October 2022.

Comparison of observations and photographs taken during the October 2022 food event on the Maribyrnong River to the DEWLP 1% (1 in 100) AEP flood extent show that the October 2022 event was close to, but slightly less than the mapped extents. In certain locations it was possible to precisely compare flood photos with mapped extents such as Affon Street and The Boulevard in Aberfeldie and the Princes Highway in Kensington. In these locations, the observed flood extent was slightly less than the mapped flood extents.

# Appendix A. Deep Creek and Maribyrnong River Flood Frequency Analysis

## A.1 Flood frequency analysis

The at-site Flood Frequency Analysis (FFA) for the Deep Creek at Darraweit Guim Gauge and Maribyrnong River at Keilor Gauge have been undertaken according to the guidelines provided in Book 3, Chapter 2 of ARR 2019. The FFA was undertaken using the TUFLOW Flike (Flike) software package. Flike provides a Bayesian framework for comprehensive at-site flood frequency estimation that allows the inclusion of ungauged historical events.

The fitting of flood frequency distributions using Flike was undertaken with the following steps:

1) Prepare data:
    a) Collect gauged streamflow data
    b) Collect historic data, including the review of previous studies
    c) Undertake review and standard data checks on the stream flow data including checking error codes, cataloguing data gaps and undertaking visual inspections
    d) Determine the water year
    e) Extract the annual maximum series and check peaks for independence
2) Using Flike, fit an extreme value distribution to the annual maximum series, including the influence of:
    a) Historic data (data that exists beyond the extent of the annual maximum series)
    b) Censoring low flows with a multiple Grubbs-Beck test

## A.2 Annual maximum flows

### A.2.1 Deep Creek at Darraweit Guim

The Deep Creek at Darraweit Guim has stream gauge records available for two locations, the sources of which are listed in Table 8. The Bureau gauge 230100A has a longer, more up to date flow record and is located approximately 3 km downstream of the DEWLP gauge 230208.

A review of the data found inconsistencies in the gauged levels and flows recorded at the two locations, which are expected due to the presence of a tributary (Boyd Creek, catchment area approx. 150 $km^2$) flowing into Deep Creek between the two sites. A significant high flow event with a peak of 537 $m^3/s$ was recorded only at the 230208 gauge in 1975 (almost double the peak flow of the October 2022 event, 280 $m^3/s$). Confidence in this 1975 flow estimate at the 230208 gauge is low due to the following:

- Stage data for the same gauge (230208) does not indicate a high flow event of this magnitude occurred on this date (peak stage: 5.18 m). It is possible that the rating curve for the gauge is of low quality for these stages.
- There is no evidence of a high flow event of a similar magnitude from a review of gauged records upstream and downstream along Deep Creek or the Maribyrnong River.
- There are no records of reported flooding in media reports for 1975.
- For these reasons, the 1975 537 $m^3/s$ event was discounted from the FFA.
- There is no data available from the 230100A gauge for this date.

Given the longer record available and higher confidence in the peak flow data available from the Bureau's 230100A gauge, the annual maxima values extracted from this site were adopted for the FFA. The gauge has a relatively complete record, as seen in Figure 20. In addition to gauged data, one historic event of 193 $m^3/s$

in 1964 recorded in the "Blue Books"[24] was added to the annual maxima series. The final adopted annual maxima series consists of 49 years from 1964 to 2022 as presented in Figure 21 and Table 9.

**Table 8: Streamflow gauges and data sources available for Deep Creek at Darraweit Guim**

| Data | Period of record | Source | Catchment area (approx.) |
|---|---|---|---|
| The Bureau Deep Creek at Darraweit Guim level and streamflow data (230100A) | 1975 – present | www.bom.gov.au/waterdata/ | 500 km$^2$ |
| DEWLP Deep Creek at Darraweit Guim level and streamflow data (230208) | 1975 – 1994 | www.bom.gov.au/waterdata/ | 350 km$^2$ |

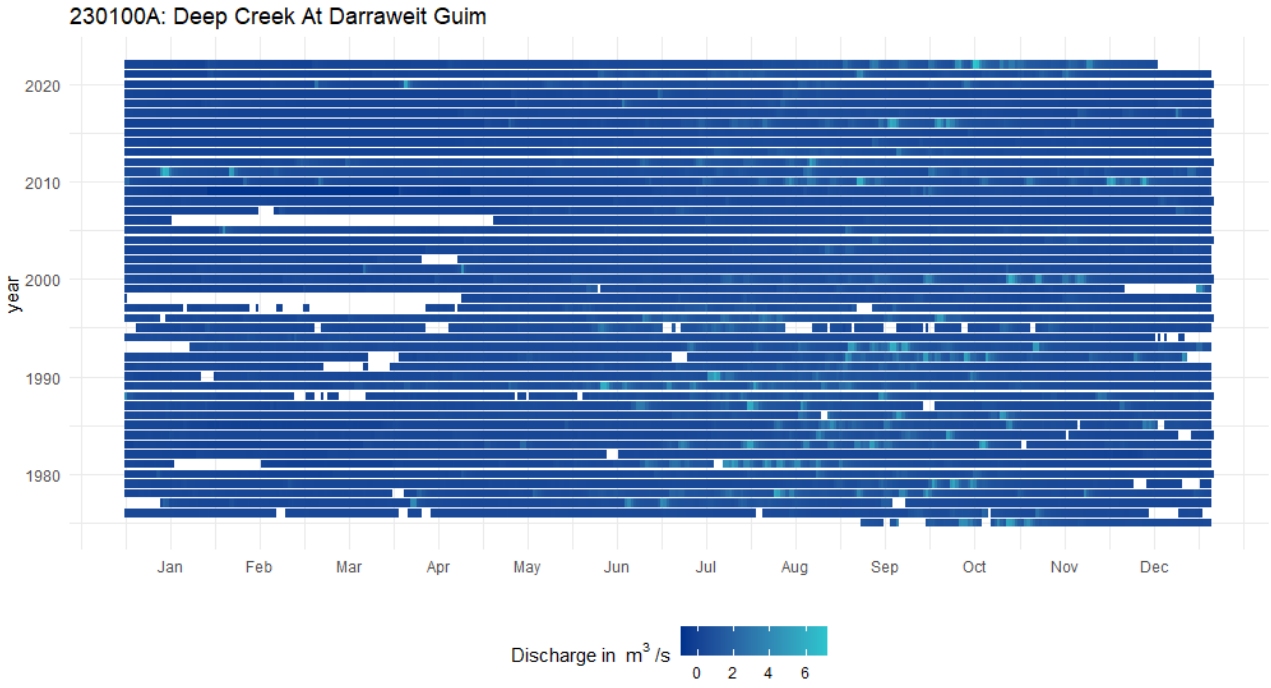



**Figure 20: Available data for Deep Creek at Darraweit Guim (230100A)**

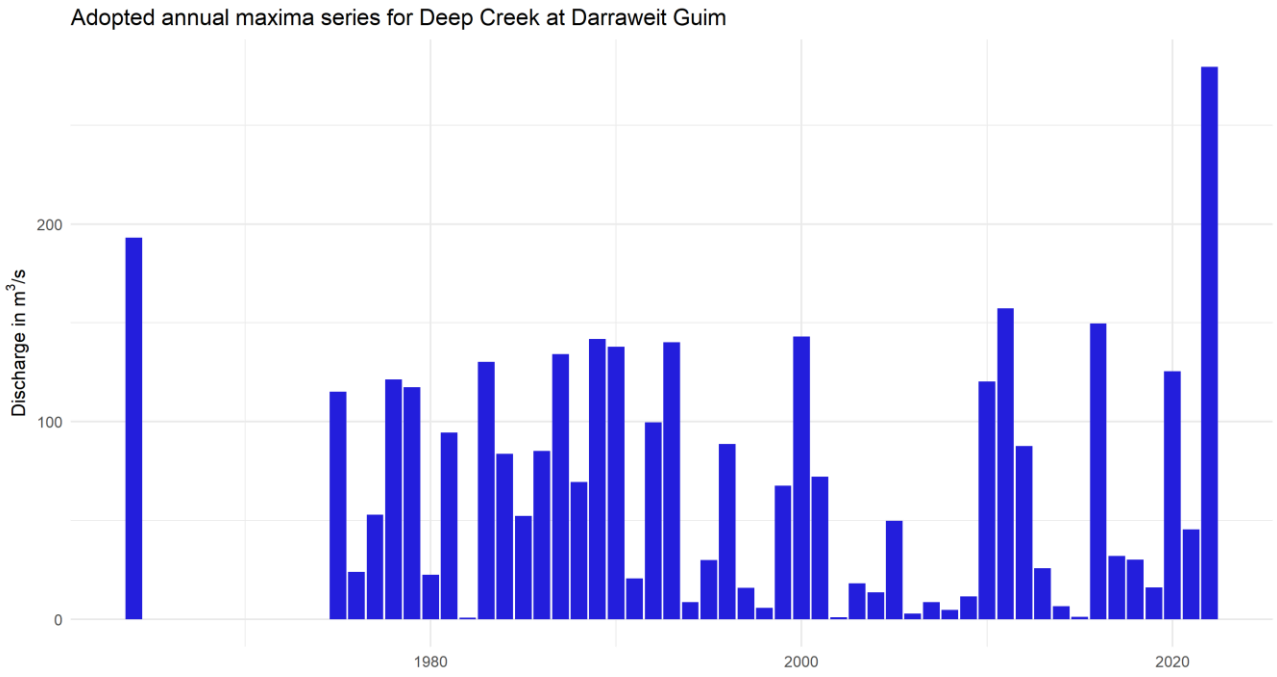



**Figure 21: Deep Creek at Darraweit Guim adopted annual maxima series**

**Table 9: Deep Creek at Darraweit Guim adopted annual maximum flows**

| Year | Flow ($m^3/s$) | Year | Flow ($m^3/s$) |
|---|---|---|---|
| 1964 | 193 | 1999 | 68 |
| 1975 | 115 | 2000 | 143 |
| 1976 | 24 | 2001 | 72 |
| 1977 | 53 | 2002 | 1 |
| 1978 | 121 | 2003 | 18 |
| 1979 | 117 | 2004 | 14 |
| 1980 | 22 | 2005 | 50 |
| 1981 | 94 | 2006 | 3 |
| 1982 | 1 | 2007 | 9 |
| 1983 | 130 | 2008 | 5 |
| 1984 | 84 | 2009 | 12 |
| 1985 | 52 | 2010 | 120 |
| 1986 | 85 | 2011 | 157 |
| 1987 | 134 | 2012 | 88 |
| 1988 | 69 | 2013 | 26 |
| 1989 | 142 | 2014 | 7 |
| 1990 | 138 | 2015 | 1 |
| 1991 | 21 | 2016 | 150 |

| Year | Flow ($m^3/s$) | Year | Flow ($m^3/s$) |
|---|---|---|---|
| 1992 | 100 | 2017 | 32 |
| 1993 | 140 | 2018 | 30 |
| 1994 | 9 | 2019 | 16 |
| 1995 | 30 | 2020 | 125 |
| 1996 | 89 | 2021 | 45 |
| 1997 | 16 | 2022 | 280 |
| 1998 | 6 | | |

### A.2.2 Maribyrnong River at Keilor

The Maribyrnong River at Keilor (230105A) stream gauge has records available from different sources, listed in Table 10.

**Table 10: Streamflow data sources available for the Maribyrnong River at Keilor (230105A)**

| Data | Period of record | Source |
|---|---|---|
| DEWLP Maribyrnong at Keilor continuous streamflow data | 1908 – present | data.water.vic.gov.au |
| The Bureau Maribyrnong at Keilor continuous streamflow data | 1975 – present | www.bom.gov.au/waterdata/ |
| MMBW partial series of flows for Maribyrnong at Keilor – used to extend the recorded gauge stages record. | 1871 – 1986 | Metropolitan Board of Work (MMBW) Maribyrnong River Flood Mitigation Study (March 1986) |

A review was carried out, whereby annual maximum flows were extracted from continuous flow records and crosschecked against all data for discrepancies. Annex 1 provides the full annual maxima series for each data source, along with details on data gaps and justification on adopted values. The DEWLP gauge record was found to be suitable for use in most instances, a plot of the available data is shown in Figure 22. DEWLP gauge records were the most complete with the following characteristics:

- A relatively complete record from 1908 to 1934 with some gaps as shown in Figure 22
- No data from 1934 to 1948
- Continuous data from 1948 to present although there are some significant data gaps between 1956 and 1968.

Review of this gauge found that there were 27 years of missing annual maxima data due to missing years or gaps in the continuous flow record. Data from either MMBW or the Bureau's records were adopted in some instances (5 years) where uncertainty around DEWLP's records was present due to missing data.

The adopted annual maxima series consists of 90 years from 1906 to 2022 as presented in Figure 23 and listed in Table 11.

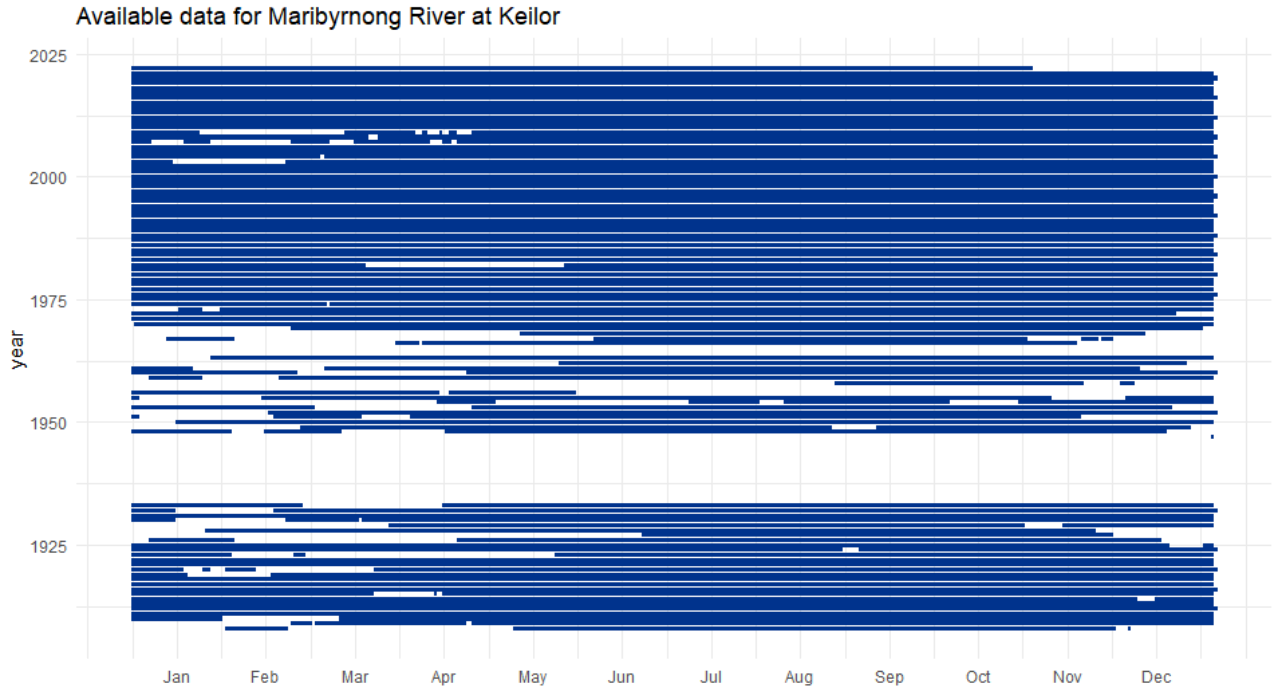



**Figure 22: Available data plot Maribyrnong River at Keilor**

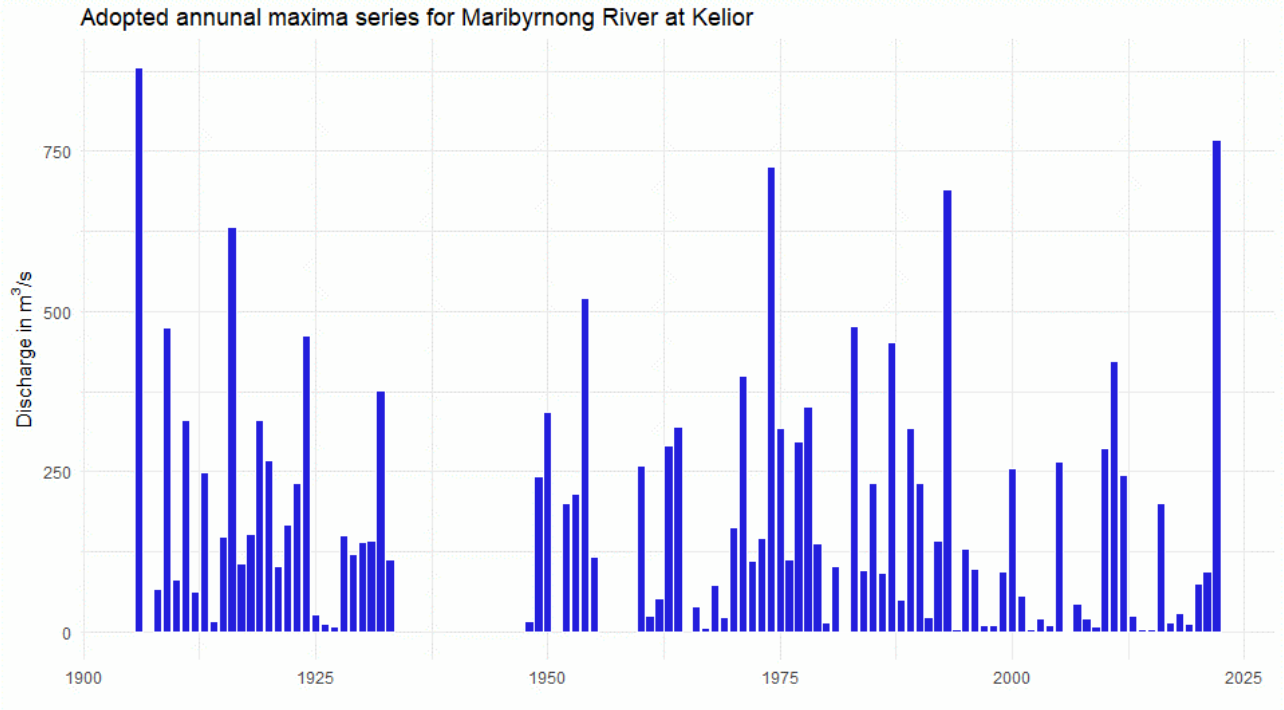



**Figure 23: Maribyrnong River at Keilor adopted annual maxima series**

**Table 11: Maribyrnong River at Keilor adopted annual maximum flows.**

| Year | Flow ($m^3/s$) | Year | Flow ($m^3/s$) | Year | Flow ($m^3/s$) | Year | Flow ($m^3/s$) |
|---|---|---|---|---|---|---|---|
| 1906 | 880 | 1933 | 112 | 1983 | 476 | 2008 | 20 |
| 1908 | 66 | 1949 | 243 | 1984 | 96 | 2009 | 9 |
| 1909 | 474 | 1950 | 343 | 1985 | 233 | 2010 | 287 |
| 1910 | 81 | 1952 | 201 | 1986 | 91 | 2011 | 423 |
| 1911 | 330 | 1951 | 314 | 1987 | 451 | 2012 | 245 |
| 1912 | 62 | 1953 | 215 | 1988 | 50 | 2013 | 25 |
| 1913 | 249 | 1954 | 520 | 1989 | 317 | 2014 | 3 |
| 1914 | 17 | 1955 | 116 | 1990 | 232 | 2015 | 5 |
| 1915 | 149 | 1959 | 43 | 1991 | 22 | 2016 | 201 |
| 1916 | 632 | 1960 | 260 | 1992 | 143 | 2017 | 14 |
| 1917 | 106 | 1963 | 291 | 1993 | 690 | 2018 | 30 |
| 1918 | 153 | 1964 | 320 | 1994 | 4 | 2019 | 12 |
| 1919 | 330 | 1969 | 22 | 1995 | 129 | 2020 | 76 |
| 1920 | 268 | 1970 | 164 | 1996 | 99 | 2021 | 93 |
| 1921 | 103 | 1971 | 399 | 1997 | 10 | 2022 | 768 |
| 1922 | 168 | 1972 | 110 | 1998 | 10 | | |
| 1923 | 232 | 1973 | 146 | 1999 | 93 | | |
| 1924 | 461 | 1974 | 726 | 2000 | 256 | | |
| 1925 | 28 | 1975 | 317 | 2001 | 57 | | |
| 1926 | 13 | 1976 | 112 | 2002 | 3 | | |
| 1928 | 151 | 1977 | 297 | 2003 | 20 | | |
| 1929 | 121 | 1978 | 352 | 2004 | 11 | | |
| 1930 | 139 | 1979 | 138 | 2005 | 265 | | |
| 1931 | 143 | 1980 | 14 | 2006 | 2 | | |
| 1932 | 376 | 1981 | 103 | 2007 | 43 | | |

## A.3 Historic information

A review of historic information was completed to validate the annual maxima series, with particular focus on the early period of record, as there was greater uncertainty in earlier records prior to commencement of continuous gauging.

### A.3.1 Deep Creek at Darraweit Guim

The review included data obtained from web searches of local media reports and historic newspaper archives obtained from Trove (trove.nla.gov.au, accessed on 13/12/2022). Given the small settlement size and rural location of Darraweit Guim, limited historic references could be located. Historic flooding has nevertheless

been reported at Darraweit as early as 1916, listed in Table 12, the same year as known flooding in the lower Maribyrnong catchment (see Section A.3.2).

**Table 12: Summary of historic information and newspaper reports relating to large historic flood events on Deep Creek at Darraweit Guim.**

| Year | Report | Report date | Source & hyperlink |
|---|---|---|---|
| 1916 | Reports of '*unprecedented damage*' in the Darraweit Guim areas where floodwaters swept away bridges, roads and other infrastructure. The flooding was the '*most destructive in the history of the district, and the loss [was] estimated at thousands of pounds'.* | 25/10/2016 | The Age |

### A.3.2 Maribyrnong River at Keilor

The review included data from newspaper archives and media reports obtained from Trove (trove.nla.gov.au, accessed on 2/11/2022) and information listed in the Melbourne and Metropolitan Board of Work (MMBW) Maribyrnong River Flood Mitigation Study (March 1986). A number of historic flood events were reported in newspapers from as early as 1883. Table 13 summarises key reports relating to large flood events on the Maribyrnong River prior to 1960.

This review resulted in the incorporation of the 1871, 1891, 1901 and 1906 flood events in the FFA as historic events. This review also confirmed the 1954 flood and indicated that there were no records of large floods in the large data gap from 1956 to 1968.

**Table 13: Summary of historic information and newspaper reports relating to large historic flood events on the Maribyrnong River.**

| Year | Flow ($m^3/s$) (rank) | Report | Report date | Source & hyperlink |
|---|---|---|---|---|
| 1871 | 600 (6) | Reports in 1906 (rank 1) confirm that flooding reached a stage 'higher than the flood of 1871'. This confirms the original ranking and occurrence of a major event during this year. Maribyrnong River also referred to as the Saltwater River. | 10/9/1906 | The Argus |
| 1883 | - | Reports in 1891 refer to observing the 'biggest flood for eight years' – however there are no records with sufficient information to validate this. This could be an error and the report meant in 20 years. | 26/6/1891 | The Age |
| 1891 | 560 (7) | Heavy flooding reported in June 1891– threat to life and property.<br>The impact of bridges on the river damming back waters was noted by newspapers. | 26/6/1891<br>18/7/1891 | The Age<br>Independent |
| 1901 | 320 (21) | Reports in 1932 noted the 'heaviest rainfall since 1901'. No further reports to provide additional details. | 14/10/1932 | The Age |
| 1906 | 880 (1) | Numerous newspaper reports on the magnitude, impact and devastation of this event in September 1906 – largest flood on record.<br>Notable remarks:<br>• River reached half a mile wide at Maribyrnong Road bridge | 15/9/1906<br>10/09/1906 | Independent<br>The Argus |

| Year | Flow ($m^3/s$) (rank) | Report | Report date | Source & hyperlink |
|---|---|---|---|---|
| | | • Water reached depth of 7ft at Maribyrnong Hotel (present day Burton Crescent) (measured against lamppost)<br>• Unprecedented damage to property and livestock<br>• Loss of life<br>• Weakness of city's drainage network noted<br>• Rain fell continuously for 12 hours with the total falls ranging from 70mm at Maribyrnong to 125mm at Deep Creek in the upper catchment (MMBW, 1986)<br>The railway bridge was '*ascribed the bulk of the damage*', which held back tons of debris and '*dammed back the force of the water and drove it along the railway embankment*'<br>Photographs of devastation and damage published.<br>Several reports about calls for funding and flood mitigation increased since this event. | 15/9/1906 | Leader |
| 1909 | 474 (10) | Reports of flooding where the river rose 9ft in a few hours - tea houses, pleasure gardens, boat quays and Anglers Rest Hotel was half submerged. Spongs Hotel isolated (see photos in 'Leader'). Trams impacted. The report mentions that September 1906 flood was 4ft higher than this flood. | 20/9/1909 | The Herald<br>Leader |
| 1910 | - | New Maribyrnong Bridge almost completed – report notes that old bridge was acting as barrier to flow. The new bridge will positively impact flood levels up and downstream, benefiting the low-lying land on the west side of the bridge. | 24/8/1910 | The Herald |
| 1916 | 632 (5) | Anxiety of residents reported upon in newspapers with relatively recent memory of the 1906 event.<br>Reports note the change in flood conditions since the upgrade of the railway bridge at Footscray and the old Maribyrnong Road bridge – removal of obstructions, flow and channel now unimpeded. However, they also note that compared to the last large flood (1906) there had been more development/properties built on low-lying land/floodplain areas.<br>Further calls for flood relief channels and levees to be built. | 27/9/1916<br>28/9/1916 | The Age<br>The Essendon Gazette and Keilor, Bulla and Broad-meadows Reporter |
| 1924 | 461 (11) | Reports of flood events in August and October 1924. Property and businesses flooded. | 27/8/1924<br>7/11/1924 | The Herald<br>The Argus |
| 1932 | 376 (15) | Reports of this event being the 'largest flood since 1916'. This is an inconsistency given that 1924's flood was larger, however reasons for this could include the speed at which waters rose and/or lack of prior warning of a flood, making the impact more pronounced.<br>Footscray Road behind racecourse 'turned into a lake'. Anglers Arms Hotel ground floor rooms inundated with water up to 4ft. Boats were torn from moorings.<br>Heavy rains combined with saturated ground and snow melt in upper catchment. Quick event – very little/no warning.<br>The river went from normal levels to +over 8ft in 4 hours. | 30/8/1932<br>31/8/1932 | The Herald<br>The Age |
| 1942 | - | Report confirming that a flood as large as 1906 had not occurred since. Houses were now built in areas that were flooded back in | 24/4/1942 | Sunshine Advocate |

| Year | Flow ($m^3/s$) (rank) | Report | Report date | Source & hyperlink |
|---|---|---|---|---|
| | | 1906 – residents were worried about potential flooding if a large event were to happen again. | | |
| 1954 | 520 (8) | Flooding reported with significant damage to property for several events over Nov-Dec period. Some properties flooded 4 times in 7 weeks. Evacuations, rescues, power outages and travel disruptions (airport closed) reported. | 13/12/1954<br>14/12/1954 | The Age<br>The Argus |

## A.4 Removal of probable influential low flows

During the period of record there were several low flow years. Low flows were censored from the dataset to ensure that these did not unduly affect the fit of the flood frequency curve.

### A.4.1 Deep Creek at Darraweit Guim

A low flow discharge threshold of 67.6 $m^3/s$ was determined by using the multiple Grubbs-Beck test which resulted in 25 events being censored.

### A.4.2 Maribyrnong River at Keilor

A low flow discharge threshold of 76 $m^3/s$ was determined by using the multiple Grubbs-Beck test which resulted in 27 events being censored.

## A.5 Flood frequency analysis results

### A.5.1 Deep Creek at Darraweit Guim

The results of the FFA for the Deep Creek at Darraweit Guim gauge are shown in Table 15 and Figure 25. The best fit to the annual maximum data series was achieved using Bayesian framework and a Log Pearson III (LP3) probability model.

**Table 14: Deep Creek at Darraweit Guim FFA Results**

| AEP | Expected Quantile ($m^3/s$) | Lower 90% Quantile Confidence Limits ($m^3/s$) | Upper 90% Quantile Confidence Limits ($m^3/s$) |
|---|---|---|---|
| 20% | **120** | 101 | 148 |
| 10% | **160** | 132 | 202 |
| 5% | **200** | 162 | 261 |
| 2% | **255** | 197 | 360 |
| 1% | **300** | 221 | 452 |
| 0.5% | **340** | 240 | 580 |

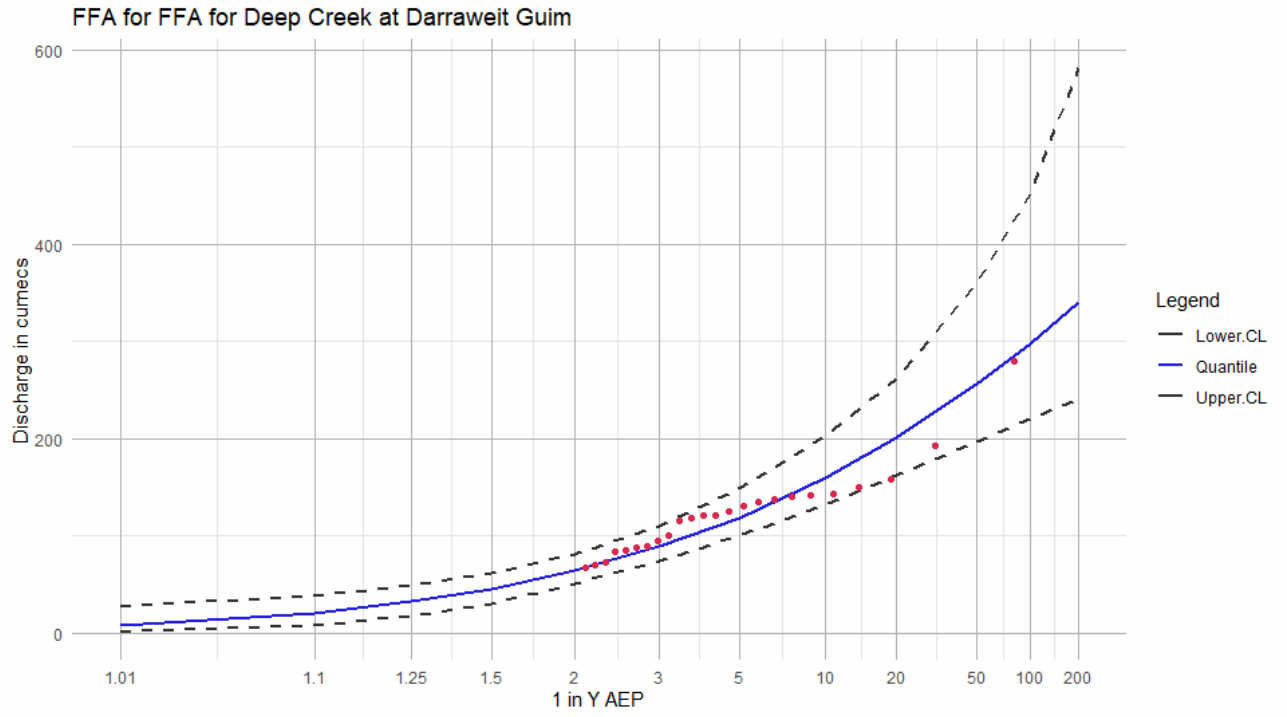



**Figure 24: Deep Creek at Darraweit Guim FFA results**

### A.5.2 Maribyrnong River at Keilor

The results of the FFA for the Maribyrnong River at Keilor gauge are shown in Table 15 and Figure 25. The best fit to the annual maximum data series was achieved using Bayesian framework and a Log Pearson III (LP3) probability model.

**Table 15: Maribyrnong River at Keilor FFA Results**

| AEP | Expected Quantile ($m^3/s$) | Lower 90% Quantile Confidence Limits ($m^3/s$) | Upper 90% Quantile Confidence Limits ($m^3/s$) |
|---|---|---|---|
| 20% | **285** | 240 | 340 |
| 10% | **420** | 360 | 500 |
| 5% | **565** | 470 | 690 |
| 2% | **760** | 610 | 1005 |
| 1% | **915** | 705 | 1320 |
| 0.5% | **1070** | 785 | 1700 |

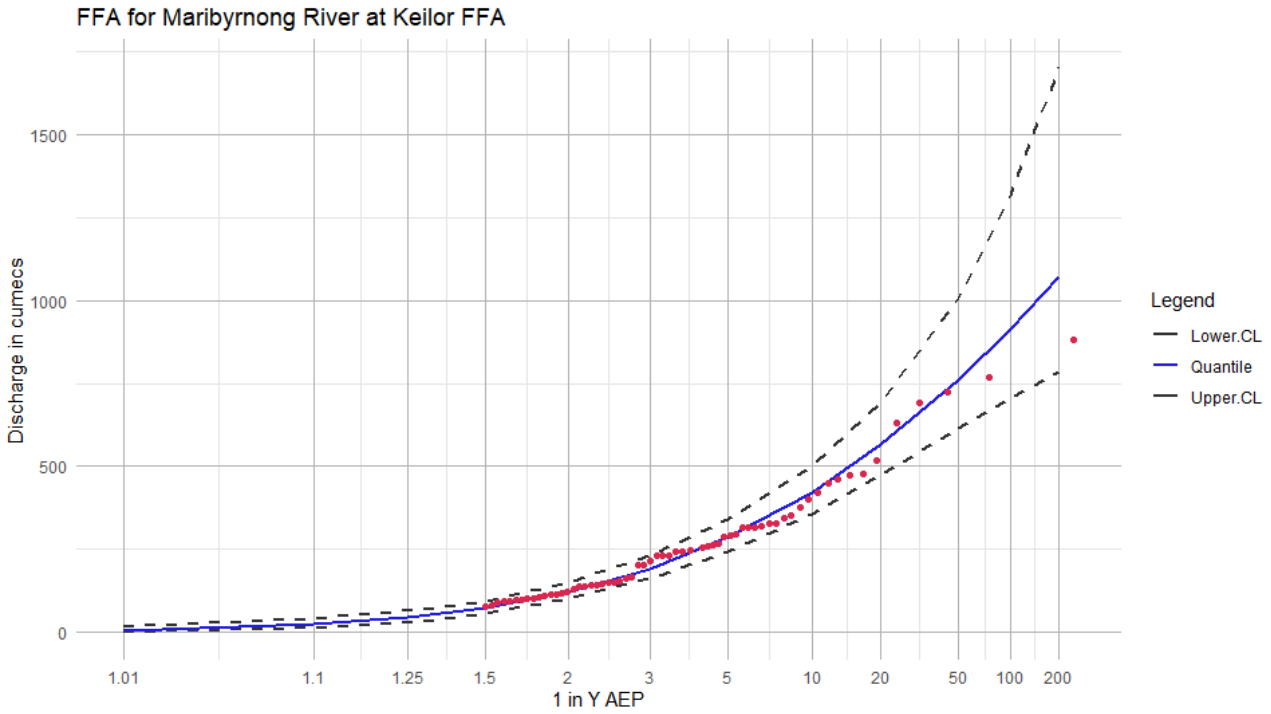



**Figure 25: Maribyrnong River at Keilor FFA results**

## A.6 Comparison with previous estimates

### A.6.1 Deep Creek at Darraweit Guim

No previous FFA results were available for comparison against the current analysis and results for this gauge.

### A.6.2 Maribyrnong River at Keilor

The current FFA results were compared to the flood quantiles estimated by MMBW (1986) (shown in Table 16). The estimates produced from the current study are greater than those from the previous work by between 5-9%. This due to:

- The additional 40 plus years of data
- More sophisticated analysis techniques
  - A Bayesian approach verses a method of moment approach
  - The ability to safely censor low flows
  - The incorporation of historic information

This increase in the discharge for flood quantiles can be intuitively explained by considering the occurrence of major flood events since the 1986. In the period 1871 to 1986, effectively 115 years, there were wo observed peak flows in excess of 650 $m^3/s$ (1908 - rank 1 and 1974 - rank 3). In the period since (36 years) there have been an additional two events greater than 650 $m^3/s$ (1993 - rank 4 and 2022 - rank 2). The FFA results from the current study are therefore considered reasonable, in alignment with expectations and observed/reviewed data.

**Table 16: Comparison of current Maribyrnong River at Keilor FFA results with previous MMBW (1986) estimates.**

| AEP | MMBW (1986) FFA Quantile ($m^3/s$) | Current FFA Expected Quantile ($m^3/s$) | % Change |
|---|---|---|---|
| 20% | 270 | 285 | +6% |

| AEP | MMBW (1986) FFA Quantile ($m^3/s$) | Current FFA Expected Quantile ($m^3/s$) | % Change |
|---|---|---|---|
| 10% | 400 | 420 | +5% |
| 5% | 530 | 565 | +7% |
| 2% | 710 | 760 | +7% |
| 1% | 840 | 915 | +9% |

## A.7 Annex 1 – Annual Maxima Series Review

**Table 17: Annual maxima series for each data source, details on data gaps and justification on adopted values.**

| Year | Adopted AMAX ($m^3/s$) | DEWLP ($m^3/s$) | MMBW ($m^3/s$) | BOM ($m^3/s$) | DEWLP no. missing days | Comments |
|---|---|---|---|---|---|---|
| 1871 | input as historic | | 600 | | | Prior to commencement of DEWLP gauging - MMBW value adopted |
| 1891 | input as historic | | 560 | | | |
| 1901 | input as historic | | 320 | | | |
| 1906 | 880 | | 880 | | | |
| 1907 | Excl | | | | | Missing year of DEWLP data - excluded |
| 1908 | 66 | 66 | | | 110 | |
| 1909 | 474 | 474 | 495 | | 57 | |
| 1910 | 81 | 81 | | | 39 | |
| 1911 | 330 | 330 | 329 | | 0 | |
| 1912 | 62 | 62 | | | 0 | |
| 1913 | 249 | 249 | 253 | | 0 | |
| 1914 | 17 | 17 | | | 6 | |
| 1915 | 149 | 149 | | | 22 | |
| 1916 | 632 | 632 | 642 | | 0 | |
| 1917 | 106 | 106 | | | 0 | |
| 1918 | 153 | 153 | | | 0 | |
| 1919 | 330 | 330 | 329 | | 28 | |
| 1920 | 268 | 268 | 269 | | 51 | |
| 1921 | 103 | 103 | | | 0 | |
| 1922 | 168 | 168 | | | 0 | |
| 1923 | 232 | 232 | | | 105 | |
| 1924 | 461 | 461 | 462 | | 5 | |
| 1925 | 28 | 28 | | | 11 | |
| 1926 | 13 | 13 | | | 99 | |
| 1927 | Excl | 9 | | | 206 | Incomplete DEWLP data - excluded |
| 1928 | 151 | 151 | | | 66 | |
| 1929 | 121 | 121 | | | 100 | |
| 1930 | 139 | 139 | | | 38 | |
| 1931 | 143 | 143 | | | 0 | |

| Year | Adopted AMAX ($m^3/s$) | DEWLP ($m^3/s$) | MMBW ($m^3/s$) | BOM ($m^3/s$) | DEWLP no. missing days | Comments |
|---|---|---|---|---|---|---|
| 1932 | 376 | 376 | 380 | | 33 | |
| 1933 | 112 | 112 | | | 47 | |
| 1934 | Excl | | | | 365 | Missing years of data in all records - excluded |
| 1935 | Excl | | | | 365 | |
| 1936 | Excl | | | | 366 | |
| 1937 | Excl | | | | 365 | |
| 1938 | Excl | | | | 365 | |
| 1939 | Excl | | | | 365 | |
| 1940 | Excl | | | | 366 | |
| 1941 | Excl | | | | 365 | |
| 1942 | Excl | | | | 365 | |
| 1943 | Excl | | | | 365 | |
| 1944 | Excl | | | | 366 | |
| 1945 | Excl | | | | 365 | |
| 1946 | Excl | | | | 365 | |
| 1947 | Excl | | | | 364 | |
| 1948 | Excl | 17 | | | 63 | Incomplete DEWLP data - excluded |
| 1949 | 243 | 243 | | | 80 | |
| 1950 | 343 | 343 | | | 15 | |
| 1951 | 314 | 314 | | | 106 | |
| 1952 | 201 | 201 | | | 46 | |
| 1953 | 215 | 215 | | | 67 | |
| 1954 | 520 | 343 | 520 | | 199 | DEWLP records missing part of year - MMBW value adopted |
| 1955 | 116 | 116 | | | 66 | |
| 1956 | Excl | 99 | | | 219 | Incomplete DEWLP data - excluded |
| 1957 | Excl | | | | 365 | Missing year of DEWLP data - excluded |
| 1958 | Excl | 47 | | | 276 | Incomplete DEWLP data - excluded |
| 1959 | 43 | 43 | | | 32 | |
| 1960 | 260 | 156 | 260 | | 57 | DEWLP records missing part of year - MMBW value adopted |
| 1961 | Excl | 24 | | | 69 | Incomplete DEWLP data - excluded |
| 1962 | Excl | 53 | | | 153 | Incomplete DEWLP data - excluded |
| 1963 | 291 | 223 | 291 | | 27 | DEWLP records missing part of year - MMBW value adopted |
| 1964 | 320 | | 320 | | 366 | DEWLP records missing year - adopt MMBW value |
| 1965 | Excl | | | | 365 | Missing year of DEWLP data - excluded |
| 1966 | Excl | 39 | | | 136 | Incomplete DEWLP data - excluded |
| 1967 | Excl | 6 | | | 186 | Incomplete DEWLP data - excluded |
| 1968 | Excl | 73 | | | 155 | Incomplete DEWLP data - excluded |
| 1969 | 22 | 22 | | | 58 | |
| 1970 | 164 | 164 | | | 1 | |

| Year | Adopted AMAX ($m^3/s$) | DEWLP ($m^3/s$) | MMBW ($m^3/s$) | BOM ($m^3/s$) | DEWLP no. missing days | Comments |
|---|---|---|---|---|---|---|
| 1971 | 399 | 399 | 407 | | 0 | |
| 1972 | 110 | 110 | | | 14 | |
| 1973 | 146 | 146 | | | 22 | |
| 1974 | 726 | 726 | 714 | | 1 | |
| 1975 | 324 | 288 | 320 | 324 | 0 | BoM value adopted given this was nearer to the MMBW value |
| 1976 | 112 | 112 | | 135 | 0 | |
| 1977 | 297 | 297 | 296 | 310 | 0 | |
| 1978 | 352 | 352 | 358 | 356 | 0 | |
| 1979 | 138 | 138 | | 141 | 0 | Significant BoM rating change in 1979 - assumed the rating pre-1979 is correct |
| 1980 | 14 | 14 | | 14 | 0 | |
| 1981 | 103 | 103 | | 94 | 0 | |
| 1982 | Excl | 2 | | 1 | 67 | Incomplete DEWLP data - excluded |
| 1983 | 476 | 476 | 456 | 464 | 0 | |
| 1984 | 96 | 96 | | 97 | 0 | |
| 1985 | 233 | 233 | | 233 | 0 | |
| 1986 | 91 | 91 | | 91 | 0 | |
| 1987 | 451 | 451 | | 451 | 0 | |
| 1988 | 50 | 50 | | 50 | 0 | |
| 1989 | 317 | 317 | | 317 | 0 | |
| 1990 | 232 | 232 | | 232 | 0 | |
| 1991 | 22 | 22 | | 22 | 0 | |
| 1992 | 143 | 143 | | 143 | 0 | |
| 1993 | 690 | 690 | | 690 | 0 | |
| 1994 | 4 | 4 | | 4 | 0 | |
| 1995 | 129 | 129 | | 129 | 0 | |
| 1996 | 99 | 99 | | 99 | 0 | |
| 1997 | 10 | 10 | | 10 | 0 | |
| 1998 | 10 | 10 | | 10 | 0 | |
| 1999 | 93 | 93 | | 93 | 0 | |
| 2000 | 256 | 256 | | 256 | 0 | |
| 2001 | 57 | 57 | | 57 | 0 | |
| 2002 | 3 | 3 | | 3 | 0 | |
| 2003 | 20 | 20 | | 20 | 38 | |
| 2004 | 11 | 11 | | 11 | 1 | |
| 2005 | 265 | 265 | | 254 | 0 | |
| 2006 | 2 | 2 | | 2 | 0 | |
| 2007 | 43 | 43 | | 32 | 52 | |
| 2008 | 20 | 20 | | 20 | 3 | |
| 2009 | 9 | 9 | | 9 | 62 | |
| 2010 | 287 | 287 | | 33 | 0 | |
| 2011 | 423 | 423 | | 35 | 0 | |

| Year | Adopted AMAX ($m^3/s$) | DEWLP ($m^3/s$) | MMBW ($m^3/s$) | BOM ($m^3/s$) | DEWLP no. missing days | Comments |
|---|---|---|---|---|---|---|
| 2012 | 245 | 245 | | 87 | 0 | |
| 2013 | 25 | 25 | | 25 | 0 | |
| 2014 | 3 | 3 | | 3 | 0 | |
| 2015 | 5 | 5 | | 5 | 0 | |
| 2016 | 201 | 201 | | 17 | 0 | |
| 2017 | 14 | 14 | | 14 | 0 | |
| 2018 | 30 | 30 | | 30 | 0 | |
| 2019 | 12 | 12 | | 12 | 0 | |
| 2020 | 76 | 76 | | 76 | 0 | |
| 2021 | 93 | 93 | | 93 | 0 | |
| 2022 | 768 | 768 | | 766 | 0 | |