Changes to the Intensity-Frequency-Duration (IFD) Design Rainfalls across Tasmania

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Abstract

The Bureau of Meteorology released new design rainfall estimates (IFDs) for Australia in July 2013 as part of the Australian Rainfall and Runoff revision project. There were changes in method and data availability between the old IFDs and the new IFDs. Previous comparisons showed that these changes have resulted in differences in IFDs across Australia. This paper explores the new IFDs from a Tasmanian perspective, comparing grids of the old and new IFDs for different durations and probabilities, highlighting observable differences and similarities and presenting possible reasons for these features.

For Tasmania, an additional 102 daily Bureau sites, 28 subdaily Bureau sites and 67 subdaily sites operated by other organisations were included in the rainfall database for the new IFDs. Many of these new sites are located in the data sparse region around the west coast and central plateau increasing the accuracy of the IFDs in these areas. The elevation enhancement used in the regionalisation and gridding process was found to have a significant impact in the areas of Tasmania with high topographic variation. There has also been a general decrease in subdaily IFDs at the 1% AEP frequency across much of the state. Spatial patterns across Tasmania correlated with prevailing weather patterns are evident by calculating ratios of standard durations.

The new IFDs are examined using recent rainfall events. The first example is an elevated site with high topographic variation in the northeast of the State. The second is an elevated site in the west of the State. The final example used is a lower site in a relatively flat area of the northern midlands. These examples show the changes in the IFDs at each of these specific locations, as well as demonstrating the ratios for the longer duration events and the shape of the IFD curves.

1. INTRODUCTION

The Bureau of Meteorology released new Intensity-Frequency-Duration (IFD) design rainfall estimates for Australia in July 2013. The IFDs are used for a wide range of engineering design applications and risk assessments as well as for rainfall event analysis and warning purposes. A number of papers have been written detailing the changes in method and data availability between old IFDs, provided in Australian Rainfall and Runoff 1987 (ARR87) (Pilgrim, 1987), and the new IFDs (Green *et al.* 2011; Johnson *et al.* 2012a; The *et al.* 2012; Johnson *et al.* 2012b). The main differences between the two methods are outlined in Green *et al.* (2014).

In this paper the focus is on IFDs in Tasmania, firstly discussing the effects of increased data availability through the longer period of record and inclusion of additional stations, and secondly the changed gridding processes, particularly the inclusion of an elevation parameter in the interpolation. Section 2 compares the old and new IFD rainfall values over Tasmania for several standard frequencies and durations as well as looking at the spatial patterns of the new IFDs using ratios of standard durations. Section 3 compares the old and new IFDs for three Tasmanian locations for specific rainfall events. **Figure 1** shows all of the rainfall sites used to derive the new IFDs for Tasmania. The sites shown in blue were also available to derive the old IFD. This map indicates the significant increase in coverage for the west of the State, with many of these additional sites recording sub-daily (continuous) rainfall data.

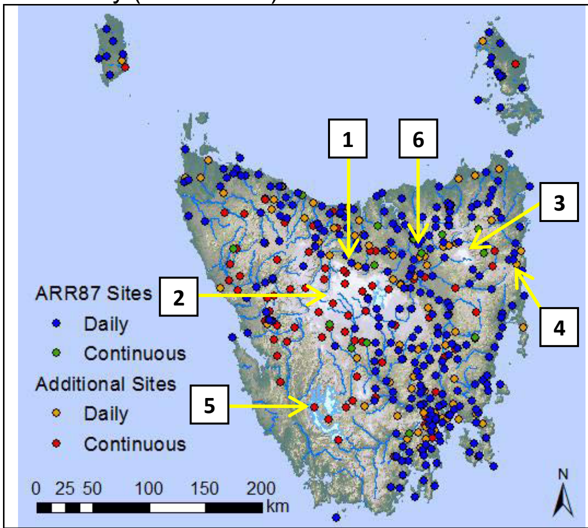


Figure 1. A map showing the rainfall sites used in the old IFDs (blue) and the additional sites used in the new IFDs (orange) for Tasmania. The locations of interest used in this paper are also indicated on the map as numbered below.

1 – Great Western Tiers

2 – Central Plateau

3 – North East Highlands

4 – Gray

5 – Strathgordon

6 – Launceston Airport

2. GENERAL PATTERNS IN THE NEW IFDS FOR TASMANIA

Two analyses have been undertaken. The first is a comparison of the differences in design rainfall depths between the old IFDs and new IFDs across a range of standard frequencies, indicating where the main changes have been for Tasmania. These are expressed in terms of depth of rainfall in millimeters for each duration and frequency. The 1EY (Exceedance per Year) values are the more frequent values while the 1% AEP values are less frequent. The second is a ratio analysis of the new IFD design rainfall depths for selected durations. This analysis seeks to provide an indication of the variation in rainfall duration across the State.

2.1. Changes in the IFDs across Tasmania

The method used to compare the old and new IFDs for Tasmania was a percentage change comparison calculated using Equation (1) from Green *et al* (2014).

Percentage Change = (New IFD – ARR87 IFD) x 100 / ARR87 IFD (1)

The digitised grids from Computerised Design IFD Rainfall System (CDIRS) based on the old IFDs from ARR87 were converted from Annual Recurrence Interval (ARI) to Annual Exceedance Probability (AEP). These are compared against the AEP grids for the new IFDs. The grid spacing for both datasets is 0.025 degrees, which works out to be approximately 2.1 square kilometers over Tasmania.

Figure 2 shows the percentage change from the old to the new IFDs over Tasmania for four standard durations (60 minutes, 12 hours, 1 day and 3 days). The maps on the left show the change for 1EY and the maps on the right show the change for 1% AEP for each of these durations. Red indicates areas where the new IFDs are less than the old IFDs and blue indicates areas where the new IFDs are greater than the old IFDs. Yellow areas show less than 10% change either way.

These results show that there are changes in all standard durations and frequencies for Tasmania, but there is not a simple pattern. In general for most of the State, the new IFDs are less than the old IFDs for the 1% AEP design rainfalls across elevated areas for durations of one day and less. In the south west of Tasmania, the new IFDs are less than the old IFDs across all durations and frequencies, most likely due to rainfall data now being available for this area. Around the Great Western Tiers and Central Plateau the new IFDs are again less than the old IFDs for the 1% AEP values, while the reverse is true for the 1EY values, decreasing the range of the IFD depth between 1EY and 1% AEP.

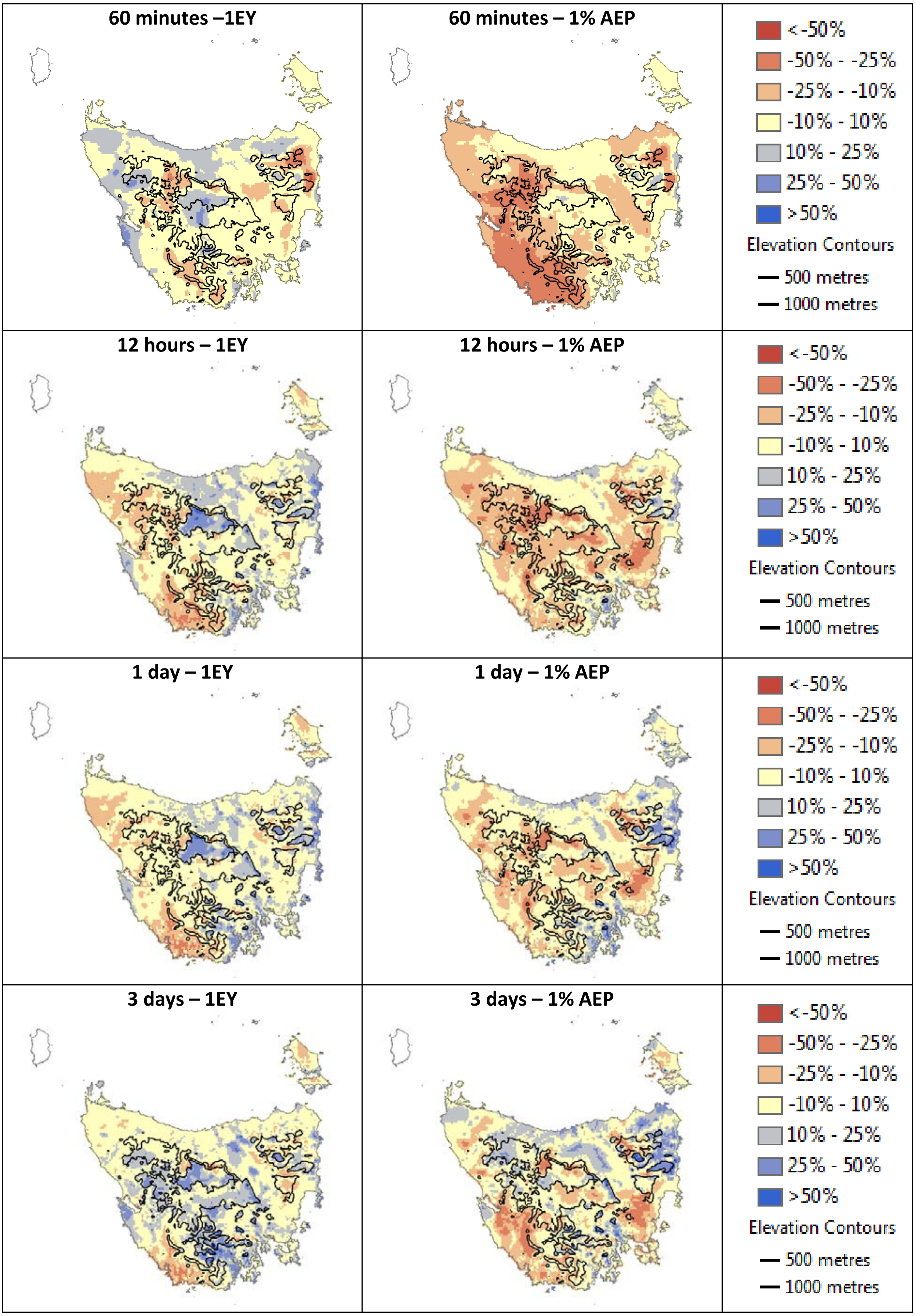


Figure 2. The percentage change between the old and new IFDs for Tasmania for 1EY (left column) and 1% AEP (right column) for four standard durations (see text for details).

Changes are more complex around the North East Highlands, where there is significant variation in topography. The elevation enhancement in the new IFD interpolation is visible in the areas with limited rain gauges. The new IFDs are significantly greater than the old IFDs for the northern East Coast around the St Helens area. This is particularly noticeable for the 1% AEP frequency.

2.2. Rainfall depths for the new IFDs across Tasmania

The new IFDs represent a wealth of information, in the form of a rigorous statistical analysis and interpolation of an extensive, quality controlled database of independent rainfall events across Australia. It was thought that this could be used to explore the general pattern of significant rainfall across Tasmania. The new IFDs grids for several standard durations were extracted for both the 1EY and 1% AEP frequencies and ratios of depths at these standard durations were then calculated.

Figure 3 shows maps of the ratios of IFD depths for Tasmania. The maps on the left show the results for the more frequent 1EY values whilst those on the right are for the less frequent 1% AEP values. The first row shows the ratio of the depths for the 7-day duration to the 1-day duration. The second row is the ratio of the depths for the 3-day duration to the 1-day duration and the third row shows the ratio of the depths for the 1-day duration to the 1-hour duration.

Over Tasmania's western highlands, the maps in the first row of **Figure 3** show that the depths for the 7-day duration for the new IFDs are at least double the depths for the 1-day duration. This pattern is particularly noticeable in the more frequent 1EY events where the ratio approaches 3.0, while the ratio for the rest of the State is generally between 1.25 and 1.5. The area is very similar to that highlighted in the study which explored the occurrence of storms on the West Coast of Tasmania (Xuereb *et al*, 2001).

The 3-day to 1-day depth ratio is also highest in the western highlands, although for the 1% AEP the North East Plateau shows similar values. These ratios are not as high as for the 7-day to 1-day ratios, with a maximum calculated value of just under 2.0. The ratio between the 1-day (24 hour) and 1-hour depths is highest around elevated areas of both the east and south west coasts. This shows that in these areas, for the less frequent events the 1-day rainfall is generally at least four times higher than the 1-hour rainfall. High ratio values greater than five particularly occur around elevated areas of the North East Plateau, Mt Wellington and the South Coast range.

3. EXAMPLES FROM SPECIFIC EVENTS

As shown in the previous section, the IFDs vary across Tasmania, as do the differences between the new IFDs and the old IFDs. In this section, these changes will be explored using three examples of recent rain events in Tasmania at different locations.

3.1. Example 1: 12 to 13 November 2013, Gray (Northeast)

On the evening of 12 November 2013, a low pressure system developed to the north of Tasmania, directing a strong easterly flow over the state. This brought heavy rain to areas of the east coast. 246mm of rainfall was reported at the automatic rain gauge at Gray (Dalmayne Road) (Bureau of Meteorology site number 092141) in the 24 hours to 9am, mostly falling in a 12 hour period overnight. The nearby manual site (092159) recorded 258 mm in the 24 hours to 9 am.

Figure 4 shows the storm event recorded by the automatic gauge plotted against both the old IFDs (red lines, labelled ARR87) and new IFDs (blue lines, labelled IFD). For the new IFDs, the storm event exceeded the 1% AEP threshold for the 6-hour duration at this location. The event appears more significant when assessed against the old IFDs. At this location there has been a significant increase in the design rainfall values across all frequencies and durations, confirming the percentage change results in **Figure 2**. The increase is most likely due to a combination of additional data and elevation enhancement. At-site analysis of the Annual Maximum Series (AMS) from nearby sites used to derive the new IFDs confirms that there have been several large rainfall events since 1984. These additional rainfall data have modified the frequency analysis and regionalisation results in the area. This trend is consistent with findings from the Climate Futures for Tasmania (Grose et al 2010).

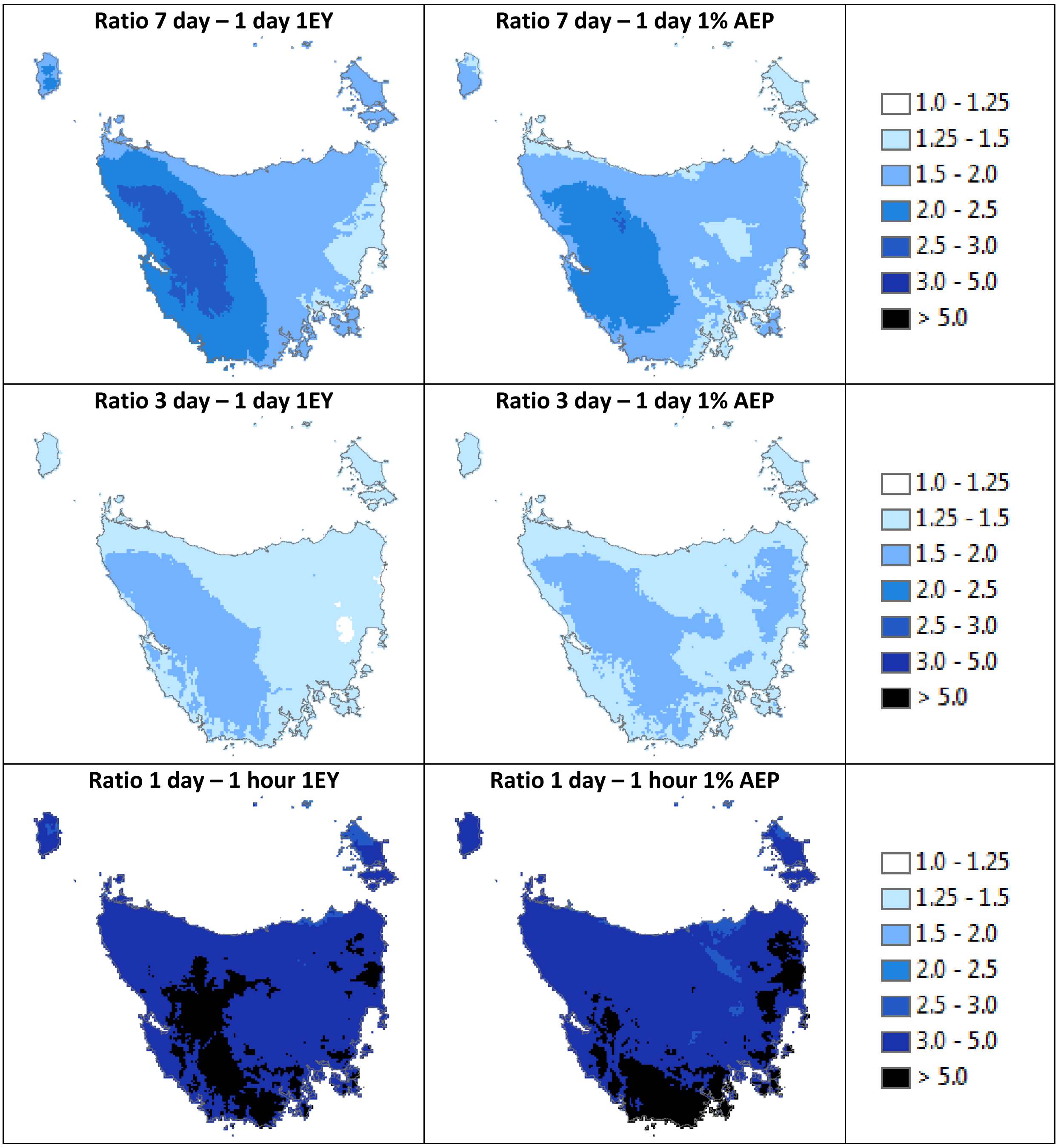


Figure 3. Comparison of duration ratios of the new IFDs for Tasmania

To examine the effects of topography, the 1% AEP for the 6 and 12-hour durations from the new IFDs for the cells surrounding the rainfall site at Gray were examined. These results are summarised in Table 1, with coordinates referring to the centre of each cell. The elevations were extracted from a 9-second Digital Elevation Model (DEM), resampled to match the grid of the IFDs.

The highlighted values in the 6-hour and 12-hour columns of **Table 1** indicate cells where the storm event exceeded the 1% AEP threshold for that cell. The cells with lower elevation to the south and southeast have lower design rainfall estimates for both durations. The range between the maximum and minimum values (northeast - southeast) for the 1% AEP for the 6 hour duration is 31.8mm while the range for the 12 hour duration is 61.4mm (again northeast - southeast). This shows the importance of selecting an appropriate location for IFD analysis in areas of high topographical variation.

Table 1. Comparison of IFDs for cells around 092141 Gray (Dalmayne Road) showing elevation and 1% AEP design rainfall estimates for the 6 hour and 12 hour durations

	Latitude	Longitude	Elevation	1% AEP 6 hour	1% AEP 12 hour	1% AEP 1 day	1% AEP 7 day	Ratio 7 day/1 day
Northwest Gray	41.6125	148.2125	298.90m	142.6	225.6	342.5	539.8	1.58
North Gray	41.6125	148.2375	507.03m	149.8	242.3	375.7	607.3	1.62
Northeast Gray	41.6125	148.2625	404.64m	156.3	252.1	386.8	612.9	1.58
West Gray	41.6375	148.2125	440.49m	150.6	242.8	374.0	598.3	1.60
Gray	41.6375	148.2375	340.34m	150.0	239.8	365.4	576.0	1.58
East Gray	41.6375	148.2625	296.12m	145.0	230.1	348.8	546.6	1.57
Southwest Gray	41.6625	148.2125	483.03m	146.0	235.6	364.8	588.6	1.61
South Gray	41.6625	148.2375	209.40m	131.1	203.8	304.8	471.3	1.55
Southeast Gray	41.6625	148.2625	101.44m	124.5	189.7	279.7	408.2	1.46

3.2. Example 2: August 2013, Strathgordon (West Coast)

During the month of August 2013, multiple cold fronts crossed Tasmania in the prevailing westerly stream, a common feature during Tasmanian winters (Grose et al 2010). Storm event analysis for this period for Strathgordon in Figure 5 shows that this was not an exceptional event for the west coast. The rainfall for the most significant 7 day period has been plotted against both the old IFDs (ARR87) and new IFDs. This shows that there has been a slight decrease in the design rainfall values across all frequencies and durations for this location. This is more notable in the shorter durations as indicated in **Figure 2**.

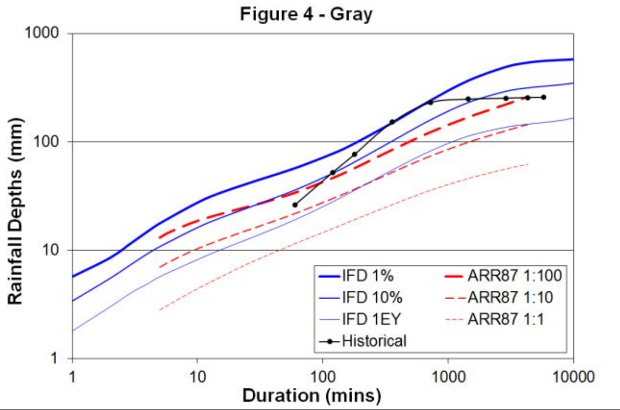
Table 2 shows the 1-day and 7-day 1% AEP design rainfall values for the cells surrounding Strathgordon. Although the DEM shows some topographic variation in the area, the IFDs are generally consistent with a range of 11.4mm for the 1-day duration and a range of 31.1mm for the 7-day duration. This lack of sensitivity to precise location is indicative of the widespread nature of the rainfall from the prevailing westerly weather. The average ratio of the 7-day to 1-day 1% AEP values is 2.19; consistent with the results shown in **Figure 3**.

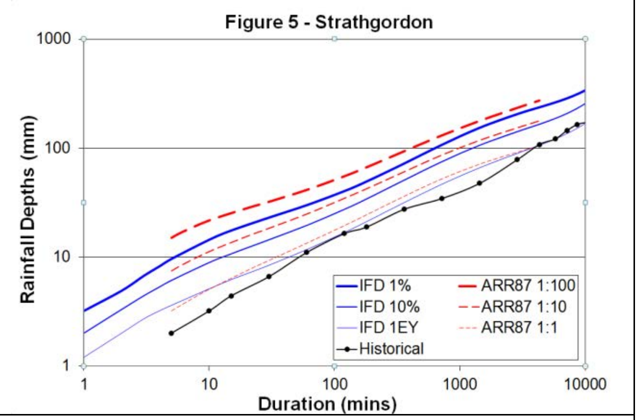
3.3. Example 3: 13 to 15 August 2013 Launceston Airport, (Central North)

A cold front crossed Tasmania during the 14 August 2013, one of the many fronts that crossed that month. It brought showers and storms to the north and west of the State with 50.4mm reported in a 24-hour period for Launceston Airport, with most of this falling within a 6-hour period. **Figure 6** shows the most significant part of the event was the 6-hour duration, with an AEP between 5 and 10% when assessed against both the old IFDs and new IFDs. Comparison of the old and new IFDs across all frequencies and durations shows that there has been little change in the design rainfall values for this location. **Table 3** shows the 1-day and 7-day 1% AEP design rainfall values for the cells surrounding Launceston Airport. The variation in elevation is low in this area and the IFDs are very similar, with a range of 10.9mm for the 1-day duration and a range of 20.2mm for the 7-day duration. The average ratio of the 7-day to 1-day 1% AEP values is 1.61; consistent with the results shown in **Figure 3**.

4. DISCUSSION AND CONCLUSIONS

For Tasmania there are spatial differences in the design rainfall values, which vary across both frequency and duration. Additional rainfall data and changes in method have resulted in differences between the old IFDs and the new IFDs. The new IFDs are only one part the design flood estimation process being updated during the ARR revision. Other key inputs affecting the design rainfall values for future design flood estimation include new temporal patterns, areal reduction factors and loss models. Overall, the combined effects of these changes in the estimation of design flows may affect future infrastructure design requirements in some parts of Tasmania, while in other areas the changes could balance out.





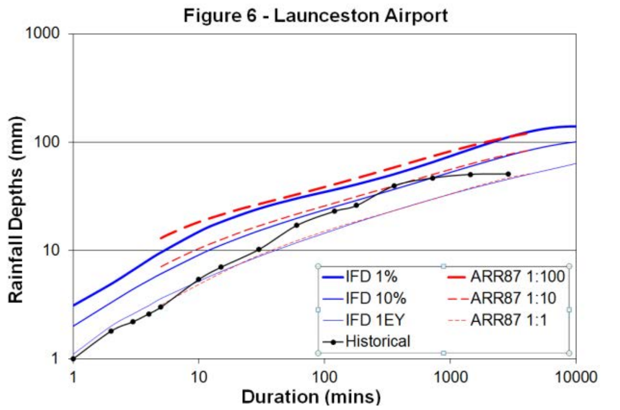


Figure 4. (Top Left) IFD comparison for 092141 Gray (Dalmayne Road) showing the storm event for the 12 – 13 of November 2013

Figure 5. (Top Right) IFD comparison for 597017 Strathgordon (Works Office) showing the most significant 7-day event from August 2013

Figure 6. (Bottom Left) IFD comparison for 091311 Launceston Airport showing the storm event for the 13 – 15 of August 2013

Table 2. Comparison of IFDs for cells around Strathgordon showing elevation and 1% AEP design rainfall estimates for the 1 day and 7 day durations

	Latitude	Longitude	Elevation	1% AEP 1 day	1% AEP 7 day	Ratio 7 day/1 day
Northwest Strathgordon	42.7375	146.0375	291.24m	142.3	309.1	2.17
North Strathgordon	42.7375	146.0625	440.09m	151.0	332.7	2.20
Northeast Strathgordon	42.7375	146.0875	438.84m	149.8	330.3	2.20
West Strathgordon	42.7625	146.0375	373.07m	148.7	324.0	2.18
Strathgordon	42.7625	146.0625	502.46m	153.7	340.2	2.21
East Strathgordon	42.7625	146.0875	415.29m	149.2	327.2	2.19
Southwest Strathgordon	42.7875	146.0375	323.00m	145.0	314.0	2.17
South Strathgordon	42.7875	146.0625	390.43m	149.2	324.9	2.18
Southeast Strathgordon	42.7875	146.0875	419.02m	149.7	327.6	2.19

Table 3. Comparison of IFDs for cells around Launceston Airport showing elevation and 1% AEP design rainfall estimates for the 1 day and 7 day durations

	Latitude	Longitude	Elevation	1% AEP 1 day	1% AEP 7 day	Ratio 7 day/1 day
Northwest Airport	41.5125	147.1875	150.55m	88.7	145.4	1.64
North Airport	41.5125	147.2125	95.44m	83.6	134.6	1.61
Northeast Airport	41.5125	147.2375	82.62m	81.7	131.2	1.61
West Airport	41.5375	147.1875	195.66m	92.4	149.9	1.62
Launceston Airport	41.5375	147.2125	147.40m	86.3	139.5	1.62
East Airport	41.5375	147.2375	88.96m	81.5	129.7	1.59
Southwest Airport	41.5625	147.1875	177.86m	90.4	146.0	1.62
South Airport	41.5625	147.2125	161.91m	87.3	140.1	1.60
Southeast Airport	41.5625	147.2375	145.70m	84.7	135.0	1.59

Higher rainfall events in the west can often be from cold fronts, which can occur over multiple days in succession. In the east, the higher rainfall events are more often from isolated and mobile cutoff low systems, reducing the chance of multi-day aggregation (Pook et al, 2010). This seems to indicate that 1EY to 1% AEP rainfall events are likely to be of longer duration in the west compared to the rest of Tasmania. Given the variation in ratios for Tasmania, consideration of the time of concentration of the catchment compared to the likely storm duration becomes important in some areas. In areas with low 7-day to 1-day ratios, the critical storm event for design flood estimation may be a shorter duration, while areas with a high ratio, the longer durations may be of importance, particularly for storage design cases. The concept of design rainfall ratios is quite new. While this paper has sought to explore the spatial distribution of these values and consider possible reasons for this, the possible applications for design and risk assessment are not fully understood and should be explored more fully.

In areas of high topographical variation, the selection of the appropriate location for the IFD analysis becomes more important as this paper shows that the IFDs generally have higher gradients in these areas. For catchment studies of design floods, the most representative cell may not be the catchment centroid. Appropriate areal reduction factors should be applied as well as consideration of partial area analysis to determine worst case (Pilgrim, 1987).

Further work in this area to integrate the new IFDs into existing design processes could include considering time of concentration, spatial distribution and antecedent catchment conditions. Analysis of key areas with changes in design flood estimation results that may affect major assets or infrastructure in terms of exceeding drainage capacity or inundation will be important as the new IFDs are adopted. More investigation of IFD ratios is required to check the connections between the gridded IFD ratio relationships for these durations. This analysis could also be extended to other states.

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