Appendix C

Memorandum

SUBJECT: Rainfall Frequency Analysis
PROJECT NUMBER: 117098

1. INTRODUCTION

The North Byron Flood Study was finalised in 2016 by BMT WBM (Reference 1) and since the completion, the Intensity-Frequency-Duration (IFD) design rainfalls available from the Bureau of Meteorology were updated to be used in conjunction with the Australian Rainfall and Runoff (ARR) (Reference 2). Byron Shire Council have engaged WMA Water to complete the North Byron Floodplain Management Study and Plan. As part of this, WMA Water have completed a Rainfall Frequency Analysis to compare the at-site gauge data to the ARR 2016 IFDs and 1987 IFD design rainfalls. The purpose of this assessment is to determine if there is any significant bias between the at-site gauge data and the ARR 2016 IFDs.

Byron Shire Council have requested the assessment be undertaken for the critical durations, the 12 hour and 24 hour storm durations, and 5 durations either side. The durations assessed in this analysis include the 30min, 1hr, 2hr, 3hr, 6hr, 12hr, 24hr, 36hr, 48hr, 72hr, 96hr and the 120hr storm duration.

The analysis established that:

- There is no evidence of consistent significant over or underestimation from the 2016 IFD estimates of rainfall depths across the study area (Section 3.3).
- The 2016 IFDs consistently provide a better fit to the observed data than the 1987 IFDs.
- Differences between the at-site gauge data and the 2016 IFDs can be explained through the use of different estimation techniques and the short record length available from the at-site gauge data (Section 2.2 and Section 3.3).
- The 2016 IFDs are fit-for-purpose to use in the North Byron Floodplain Management Study and Plan.
- The 2016 IFDs are recommended for use in conjunction with the 2016 ARR methodology, which includes the revised temporal patterns. To fully understand which approach is best suited for the North Byron Catchment a Flood Frequency Analysis of the runoff routing is required to compare the difference between the 2016 and 1987 IFDs and methodology.

2. AVAILABLE DATA

2.1. Rainfall Data

Historical rainfall data was gathered for all pluviometry gauges within the North Byron Catchment Area and gauges nearby. Figure 1 shows the location of these gauges in reference to the catchment area. Table 1 provides further information on these gauges including the supplier and record length. The gauges used within this assessment are consistent with the gauges used in the North Byron Flood Study (Table 4.1 of Reference 1).

The North Byron Flood Study notes other pluviographs within the catchment (Figure 2.5 of Reference 1). These were not included within this Rainfall Frequency Analysis or within the analysis undertaken in the Flood Study. These gauges (Table 2) are not suitable for use within this Rainfall Frequency Analysis as they are flood warning operational data and as such there is limited to no data quality control processes. In addition to this, the Bureau of Meteorology could only provide data for these gauges from 2007, which is an insufficient record length for use in Rainfall Frequency Analysis.

Table 1: Available pluviometry data within the North Byron Catchment and nearby.

Gauge	Station ID	Supplier	Latitude	Longitude	Record Length	Reading Increments
Condong Sugar Mill	058013	Bureau	-28.317	153.433	1952-1972	6 minute
Nimbin Post Office	058044	Bureau	-28.597	153.223	1963-Current	6 minute
Federal Post Office	058072	Bureau	-28.653	153.454	1965-1998	6 minute
Tyalgum	058109	Bureau	-28.369	153.171	1965-1996	6 minute
Kunghur	058129	Bureau	-28.466	153.263	1965-2008	6 minute
Alstonville Tropical Fruit	058131	Bureau	-28.852	153.456	1963-2011	6 minute
Murwillumbah	058158	Bureau	-28.34	153.381	1972-Current	6 minute
Cudgera	558046	MHL	-28.393	153.507	1984-Current	5 minute (before 2011) Instantaneous (after 2011)
Huonbrook	558049	MHL	-28.552	153.356	1986-Current	
Lake Ainsworth	203455	MHL	-28.781	153.593	1994-Current	
Main Arm	558053	MHL	-28.5	153.433	1985-Current	
Myocum	558036	MHL	-28.589	153.517	1986-Current	

Table 2: Pluviometry data not included within this Rainfall Frequency Analysis.

Gauge	Station ID
Upper Main Arm	558034
Lacks Creek (Middle Pocket)	558005
Mullumbimby Creek	558008
Byron Bay (Belongil Creek)	558066
Chincogan	558025
Yelgun Creek	558096

2.2. Intensity-Frequency-Duration (IFD) Design Rainfalls

Design rainfalls are available from the Bureau of Meteorology. The most current design rainfalls are the ARR 2016 IFDs, however the 1987 IFDs are still available from the Bureau. ARR 2016 recommends the use of the 2016 IFDs for new flood studies. As discussed in Section 1, the North Byron Flood Study used the 1987 IFDs as the 2016 IFDs were not available at the time the work was undertaken.

IFDs are a statistical estimate of design rainfalls and do not represent actual rainfall events. There are known limitations with the 2016 IFDs, however they are widely accepted as the best available estimates of design rainfall and considered a substantial improvement on the 1987 IFDs. Book 2 of ARR provides more discussion on the development of the 2016 IFDs and the associated limitations, however a summary is provided below.

- The 2016 IFDs were developed using an additional 30 years of rainfall data and included an additional 2,300 rainfall stations throughout Australia (Reference 4).
- Advances in statistical analysis techniques since 1987 means the 2016 IFDs are derived from more robust methodologies.
- Gauges which only have a relatively short record length (30-40 years) can introduce bias and uncertainty in fitting statistical distributions, as rarer rainfall events are unlikely to have been captured. The 2016 IFDs adopted a regionalisation method which looks at multiple gauges with

similar rainfall characteristics and determines a weighted L-moment. This approach means that for any given site, the rainfall estimates can be determined using up to 8-10 sites and provides a higher confidence in the distribution. This provides substantial improvement over using single gauges (the approach adopted in the 1987 IFDs).

- The 2016 IFD have known limitations in areas with steep rainfall gradients (such as Woollongong) and locations where pooled gauges may not have similar characteristics.
- Over-smoothing of the 2016 IFDs can occur where there may be too many gauges included.

Whilst not perfect, it is generally accepted that the 2016 IFDs provide the best estimate of rainfall depths available and represent a substantial improvement on the 1987 IFDs.

It should be noted that the 1987 IFDs produced intensities for different Average Recurrence Intervals, the 2016 IFDs provide rainfall depths for Exceedances per Year (EY) and Annual Exceedance Probability (AEP). It is important to note that AEPs and ARIs are not interchangeable, however this has been accounted for in the following analysis.

2.3. IFD Design Rainfalls for North Byron catchment

Design rainfalls were extracted for each gauge within the catchment for both the 1987 and 2016 IFDs (Reference 3). Figure 1 provides an example of the spatial distribution of design rainfalls (ARR 2016 IFDs) across the catchment for the 1% AEP 12 hour design storm. The 2016 and 1987 IFDs for each gauge are provided in Appendix C-1 and Appendix C-2.

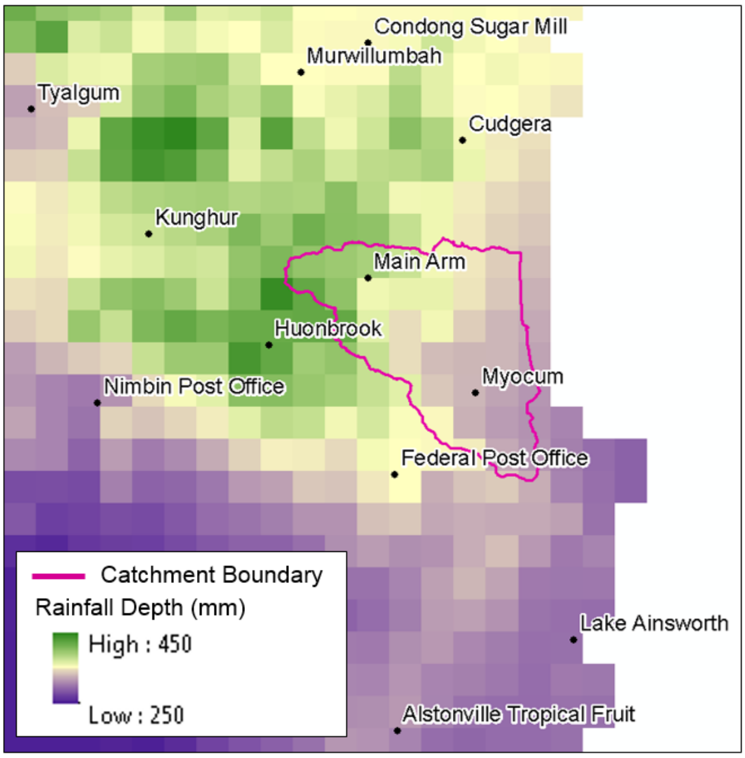


Figure 1: Spatial distribution for the 1 in 100 AEP 12 hour duration 2016 ARR IFD design rainfalls.

3. RAINFALL FREQUENCY ANALYSIS

3.1. Annual Maximum Series

Book 3 of ARR 2016 (Reference 5) provides technical guidance for flood frequency analysis. While the chapter focuses on stream flow, the principles can also be applied for rainfall frequency analysis. ARR discusses both the annual maximum series and peak-over threshold series and acknowledges the benefits and limitations of both. Use of the annual maximum series ensures events identified are independent of each other, which is important when developing a probabilistic model.

The annual maximum rainfall depth was extracted for each duration at each gauge. This was done for both the calendar year and the water year to check for differences in maximums. The water year was taken as 1 September to 31 August and was estimated based on the Bureau of Meteorology (Reference 6) online summary statistics for the daily rainfall in Mullumbimby at Fairview (Figure 2). Figure 3 shows the location of this gauge in reference to key places within the study area. This gauge has not been used within this rainfall frequency assessment and has only been used to quickly estimate the water year for the study area. Figure **2** shows that on average Mullumbimby experiences smaller rainfall depths in the middle of the year around August and September and larger rainfalls across the summer period. ARR (Reference 5) recommends where a study area experiences seasonal events the use of the water year is preferable.

Summary statistics for all years Information about climate statistics

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	205.0	233.6	247.0	176.9	167.9	135.1	95.8	74.5	60.6	105.3	121.7	151.6	1761.8
Lowest	24.4	12.8	13.7	14.5	1.3	1.3	0.0	0.0	0.0	3.0	7.3	27.8	672.0
5th %ile	38.8	37.4	46.2	27.2	13.8	14.4	1.1	3.1	2.9	13.3	18.6	36.7	1057.2
10th %ile	52.0	69.4	70.8	37.6	28.5	20.3	6.0	6.5	7.7	23.0	28.4	47.2	1174.8
Median	150.8	179.1	218.0	136.8	123.2	97.4	57.5	52.0	45.3	79.8	97.1	128.9	1673.2
90th %ile	393.0	440.6	444.8	351.8	331.6	287.3	256.7	155.2	139.8	214.5	254.1	286.7	2353.9
95th %ile	458.0	643.4	610.2	447.0	427.8	382.9	304.3	223.8	169.1	241.4	288.4	341.4	2475.4
Highest	880.8	946.5	925.0	860.8	662.6	602.2	587.1	392.7	204.8	772.3	450.0	594.0	3077.5

Figure 2: Bureau of Meteorology summary statistics for the Mullumbimby gauge at Fairview (Station ID - 58040).

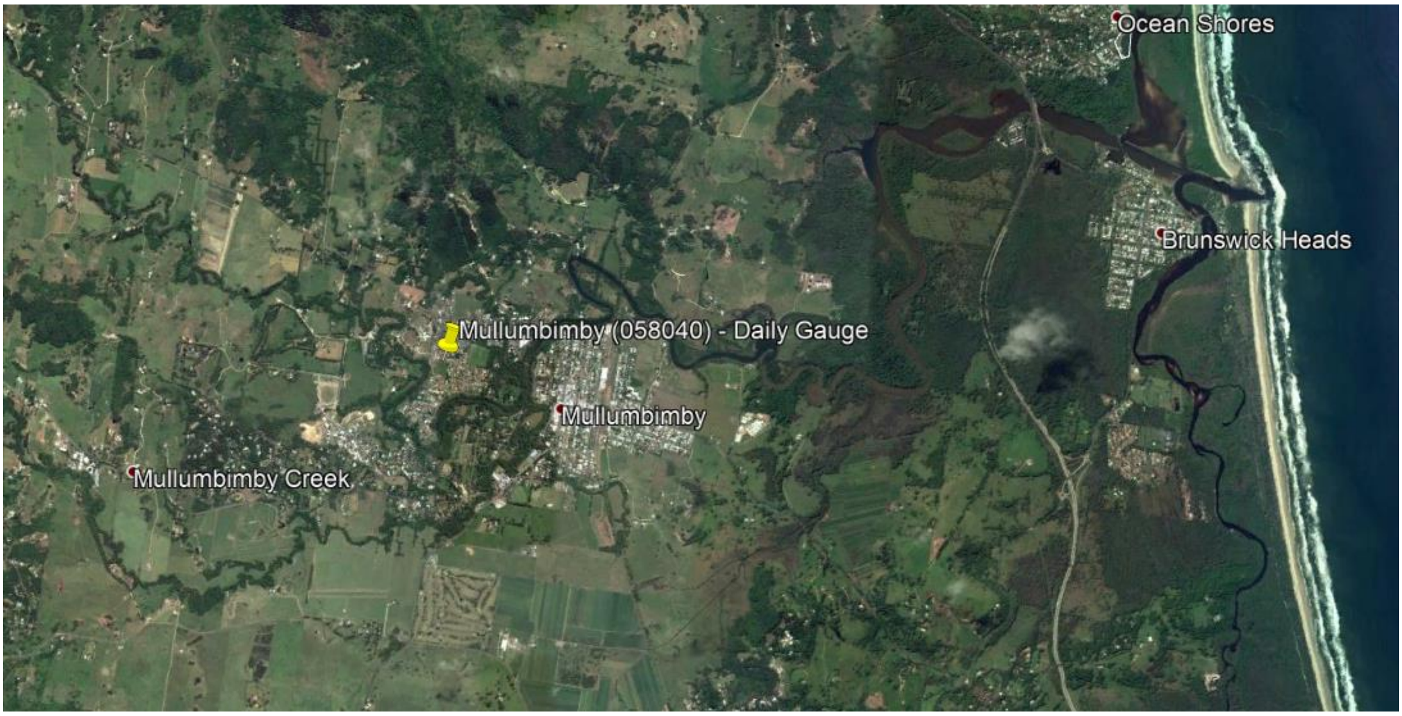
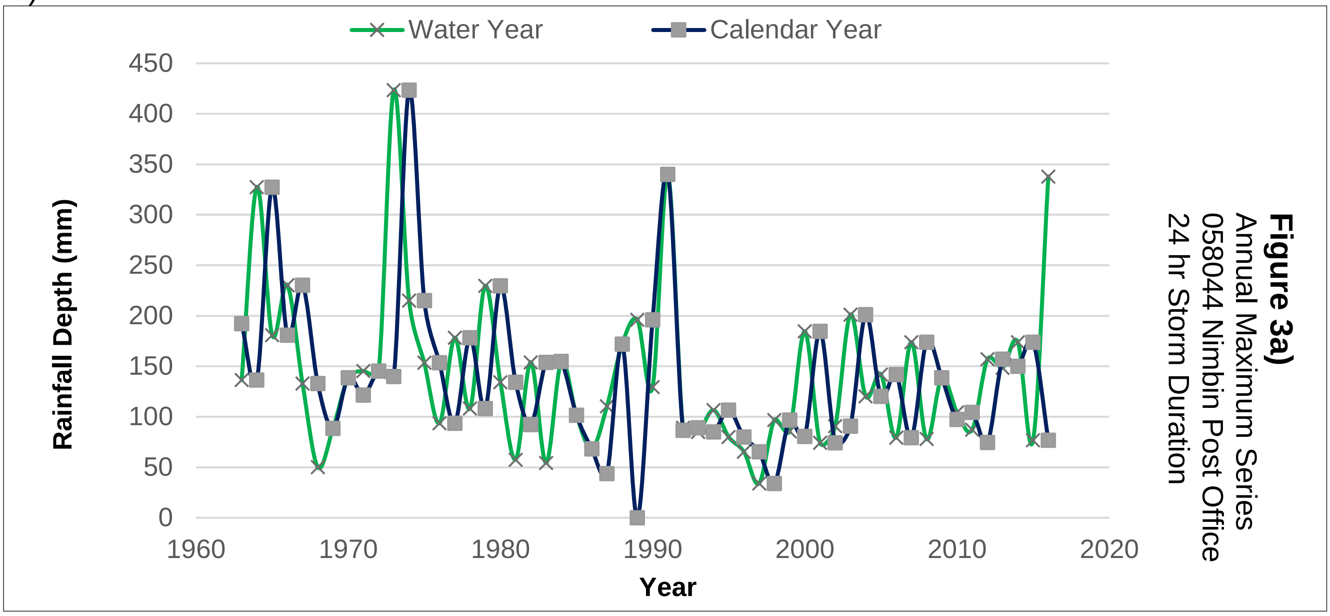


Figure 3: Location of the Mullumbimby gauge (058040). This figure is a screenshot taken from Google Earth on 8/03/18.

Figure 4 a) and b) show the annual maximum rainfalls for both the calendar year and water year. While the annual maximum series (AMS) are predominantly similar, there are a few differences between the two. This can occur when the calendar year identifies two events within the same season but spanned over two years. Typically, the use of the calendar year or water year will only marginally change the AMS and it is not expected to make a large different. However, given the seasonal nature of rainfall in the North Byron Catchment the water year has been adopted to ensure only the maximum rainfall event per season is included within the AMS.

Appendix C-3 includes the AMS adopted for each gauge and duration. It should be noted, that there may be cases where gauges failed and did not record events. Both the Bureau and Manly Hydraulics Laboratory have quality assurance processes and provide quality codes to provide an understanding of the data. There are periods where the rainfall data quality has been estimated or is suspected could be wrong and as such there are limitations with this analysis. Where data has been recorded, no rainfall events were excluded from the analysis unless there was a year without any rainfall data or for the Huonbrook gauge as is explained in Section 3.3.3. While gauges may have missed events, there is no other strong justification to exclude data where it has been recorded.

a)



b)

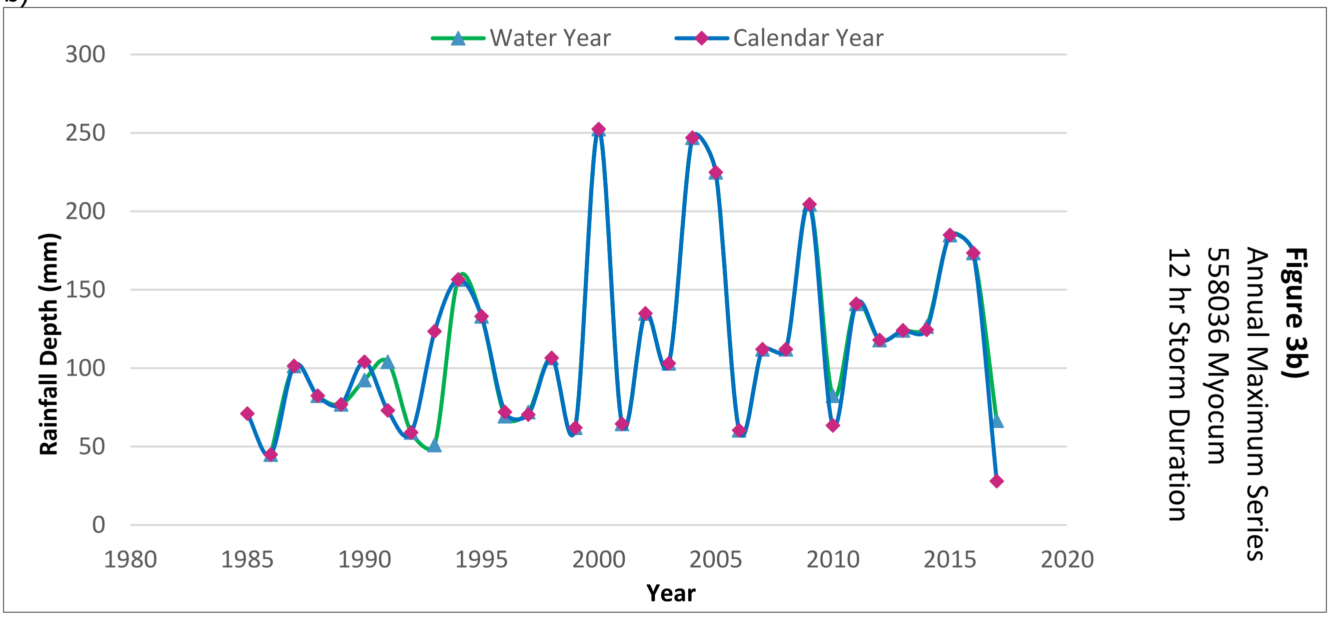


Figure 4: Comparison between the water year annual maximum series and calendar year annual maximum series.

3.2. Flike Frequency Analysis

Flike (Reference 7) is a commonly used statistical program and calculates the probability of storm events for a given historical record. For this analysis, Flike has been used to fit a Generalised Extreme Value (GEV) probability model to the at-site AMS data.

3.3. At-Site Rainfall and 2016 Design Rainfalls

The 2016 ARR IFDs and the 1987 ARR IFDs were plotted against the at-site AMS for each gauge and duration. The purpose of this assessment is to identify any bias between the at-site gauge data and the 2016

ARR IFDs, and to determine which IFDs produced the closer fit. Graphical comparisons between the IFDs and the at-site data are displayed within Appendix C-4.

This analysis looked at 12 rainfall gauges within the catchment for 12 storm durations. As detailed in Section 1, the analysis looked at the critical durations and 5 durations either side. While the 36 hour duration is not a standard duration, this has been included as it was identified as a critical duration for one of the sub catchments. In general, the figures included in Appendix C-4 show the 2016 IFDs can both over and underestimate rainfall for the study area.

While, the 2016 IFDs do not always provide a good fit when compared to the at-site AMS, there does not appear to be any overall substantial local bias to consistently over or underestimate across the study area. Section 2.2 outlines the regionalisation method used to develop the 2016 IFDs and highlights the issues that can be associated with site data. Where site data can be noisy and can create significant over or underestimations depending on record length, the 2016 IFDs were developed in a way that increases confidence in the estimates by looking at a pool of gauges and fitting the GEV distribution based on the weighted L-moment from these gauges.

The updated 2016 IFDs better represent the at-site data, particularly for the rarer storm events. There are still cases where the 2016 IFD rainfall estimates are significantly higher than the at-site gauge data. However, in saying this the average record length for the gauges included in this analysis is 40 years. This is extremely short to be accurately representing rarer events such as the 1 in 50 AEP and 1 in 100 AEP. Taking this into consideration, it is not considered unreasonable that the 2016 IFDs slightly overestimates these rarer storm events.

Of particular interest is where the 2016 IFD significantly underestimates rainfall depths. The 2016 IFD at the gauge at Alstonville Tropical Fruit, particularly for 6 hour storm duration up to the 120 hour storm duration (Figure C137 to C144), show an example of this occurring. The gauge at Alstonville Tropical Fruit is the only location within the catchment where this large underestimation occurs. This gauge experienced a significantly large event, however only has 48 years of recorded rainfall data. The occurrence of this will create vast overestimates when fitting the at-site data. This is extremely common and situations like this add further support to the regionalisation technique used for the 2016 IFDs. Given the Alstonville Tropical Fruit gauge is approximately 25 km outside of the catchment and the short record length, less weight has been given to the results from this gauge.

In addition to plotting the at-site annual maximum against the IFDs, the 2016 IFD was compared to the fitted GEV distribution for the at-site data. The results from this are included in Appendix C-5. Where the difference between the 2016 ARR IFDs and the at-site rainfall frequency analysis was greater than +/- 10% or 30% this was highlighted. It is important when looking at these results to understand this is a comparison of two statistical models. As the average gauge length is approximately 40 years it is expected the fitted distribution may not accurately represent the data.

As seen in Figure 1, the Main Arm gauge, Myocum, Huonbrook and Federal Post Office gauge are either within the North Byron catchment or closest. The following discussion in Section 3.3.1 through to Section 3.3.4 focuses on these gauges predominantly.

It is not recommended that a local correction factor be used for this study.

3.3.1. Main Arm Gauge

The comparison between the gauge at Main Arm and the 2016 ARR IFDs show no local bias for this gauge. In general, the 2016 IFDs only slightly overestimate rainfall depths for larger events. Figure 4 and 5 compare both the 2016 and 1987 IFDs against the at-site AMS for the 12 hour and 24 hour durations. This graphical comparison shows for larger AEP events in the 12 hour storm event, the 2016 IFD and the 1987 IFD tends to overestimate the rainfall. Both 2016 and 1987 IFDs represent the at-site data quite well for this storm duration.

For the 24 hour storm duration, the 2016 IFD appears to be consistent with the at-site data for the 1 in 100 AEP event and also represents the smaller events well. As the storm duration increases, the fit between the 1987 IFDs and the at-site gauge data becomes poorer, whereas the 2016 ARR IFDs continue to represent the at-site date well. These graphs can be found in Appendix C-4.

Table 3 provides a comparison between the fitted GEV distribution of the at-site gauge data and the 2016 ARR IFD. This table identifies only three instances where the difference between the at-site rainfall frequency analysis is greater than +/-10% (orange cells). As included in Section 3.3, this comparison is looking at two statistical models and this needs to be considered when assessing the two.

Table 3: Comparison between the fitted GEV distribution for at-site gauge data and 2016 ARR IFDs for Main Arm gauge.

Rainfall depth (mm) for AEPs (1 in x)							
Duration		**2**	**5**	**10**	**20**	**50**	**100**
0.5hr	558053	28.4	37.3	43	48.3	55	59.8
	2016 IFD	29.9	40	46.9	53.6	62.6	69.6
1hr	558053	37	50.9	60.9	71.1	85.3	96.7
	2016 IFD	40	54.4	64.7	75	89.4	101
2hr	558053	54.4	76.3	91.5	106.4	126.4	141.9
	2016 IFD	53.2	74.6	90.1	106	129	148
3hr	558053	65.3	94.3	114.5	134.6	161.8	183.1
	2016 IFD	63.5	90.6	111	131	161	186
6hr	558053	96.2	143.7	173.2	200.3	233.5	257.1
	2016 IFD	88.3	129	160	191	235	272
12hr	558053	128.6	195.7	237.6	276	323.2	356.9
	2016 IFD	125	186	230	276	336	384
24hr	558053	181.1	280.4	345.7	407.9	488	547.7
	2016 IFD	175	260	319	379	455	513
36hr	558053	216.1	330.5	405	475.4	565.1	631.4
	2016 IFD	209	307	375	442	526	589
48hr	558053	233.7	355.2	434.6	510	606.6	678.2
	2016 IFD	233	341	413	484	573	639
72hr	558053	263.2	393.1	475.4	551.8	647	715.7
	2016 IFD	264	383	462	538	634	706
96hr	558053	286.9	425.3	509.3	584.6	674.9	737.7
	2016 IFD	283	409	493	573	675	750
120hr	558053	296.4	437	521.9	597.7	688.4	751.2
	2016 IFD	296	428	515	599	706	785

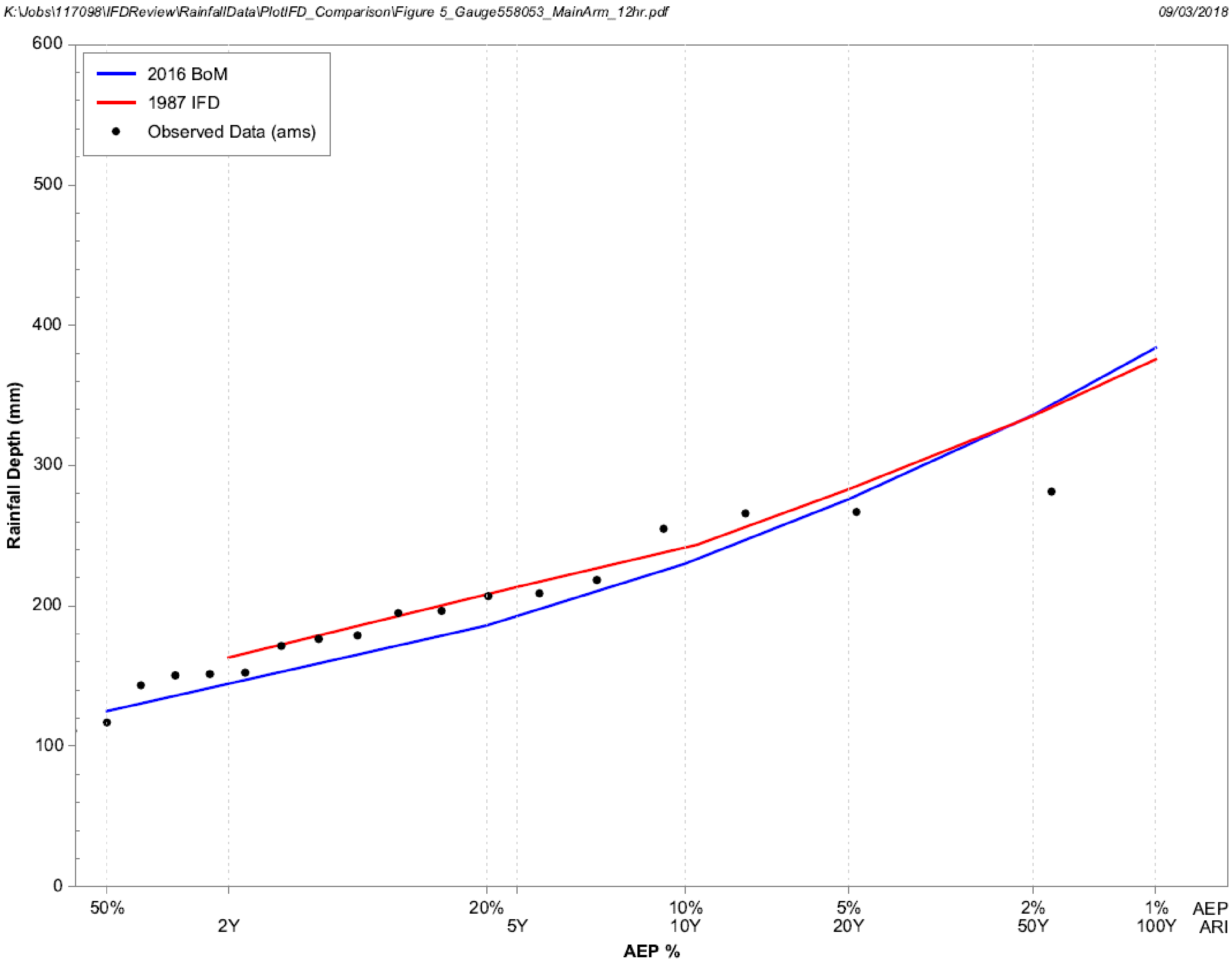


FIGURE 5
PLUVI (12 HOUR DURATION)
IFD & AMS COMPARISON
GAUGE 558053 - MAIN ARM

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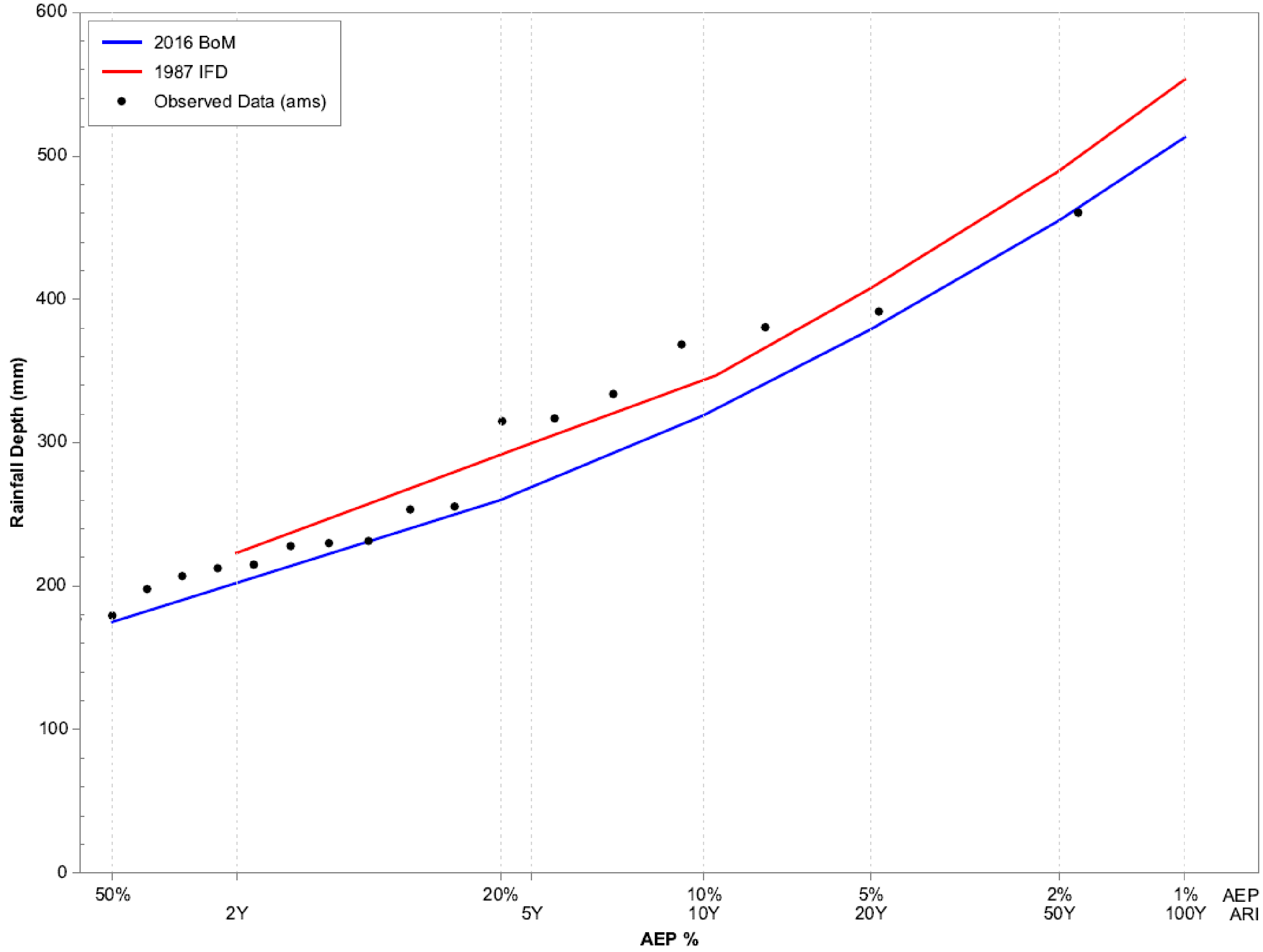

FIGURE 6
PLUVI (24 HOUR DURATION)
IFD & AMS COMPARISON
GAUGE 558053 - MAIN ARM

3.3.2. Myocum Gauge

The at-site AMS for the gauge at Myocum is plotted below in Figure 6 (12 hour) and Figure 7 (24 hour) against the 2016 and 1987 IFDs. For both storm durations the 2016 and 1987 IFDs show no local bias when compared to the at-site gauge data. While, the 2016 IFD overestimates the 1 in 100 AEP event for the 12 hour storm duration, this does not occur for the 24 hour storm duration. The agreement between the at-site gauge data and the 2016 IFDs is consistent for the other durations shown in Appendix C-4. The 2016 IFD does not show a general tends toward either over or underestimation of the rainfall depth.

Table 4 compares the rainfall frequency analysis for the at-site gauge data to the 2016 IFDs and shows more instances of a differences greater than +/-10% (orange cells) than the Main Arm rainfall frequency analysis did. There are two occurrences where the difference between the two models are greater than +/-30% (blue cells). The Myocum gauge only has a record length of 32 years. Fitting a distribution to data of only this length introduces uncertainty in the model results, particularly for the larger events. Given this, it can be concluded the 2016 IFDs accurately represent the at-site data.

Table 4: Comparison between the fitted GEV distribution for at-site gauge data and 2016 ARR IFDs for the Myocum gauge.

Rainfall depth (mm) for AEPs (1 in x)							
Duration		2	5	10	20	50	100
0.5hr	558036	30.1	38	42.3	45.8	49.6	52
	2016 IFD	29.6	39.3	45.9	52.2	60.5	66.7
1hr	558036	40.3	51.2	56.9	61.4	66.3	69.2
	2016 IFD	39.2	52.8	62.2	71.6	84.3	94.4
2hr	558036	54.2	69.7	77.8	84.3	91.2	95.5
	2016 IFD	51.3	70.6	84.4	98.4	118	134
3hr	558036	64.7	88.5	103.1	116.4	132.5	143.8
	2016 IFD	60.5	84.4	102	119	144	165
6hr	558036	85.1	119.6	143.5	167.3	199.3	224.3
	2016 IFD	81.8	116	142	168	204	233
12hr	558036	103.8	154.5	191.8	230.7	286.1	331.6
	2016 IFD	112	162	198	234	283	322
24hr	558036	135.7	209.6	265.8	326.1	414.3	488.9
	2016 IFD	152	219	267	314	376	423
36hr	558036	156.8	241	303.1	367.8	459.7	535.3
	2016 IFD	178	256	309	362	430	481
48hr	558036	165.5	255.2	326.1	404.2	522.5	625.8
	2016 IFD	196	280	337	393	465	519
72hr	558036	179.2	273.9	347.8	428.4	549.1	653.3
	2016 IFD	220	312	373	432	509	566
96hr	558036	193.2	295.6	372.3	453.4	570.2	667.6
	2016 IFD	234	330	394	456	536	596
120hr	558036	208.2	313.5	388.6	464.9	570.3	654.5
	2016 IFD	243	343	409	473	556	618

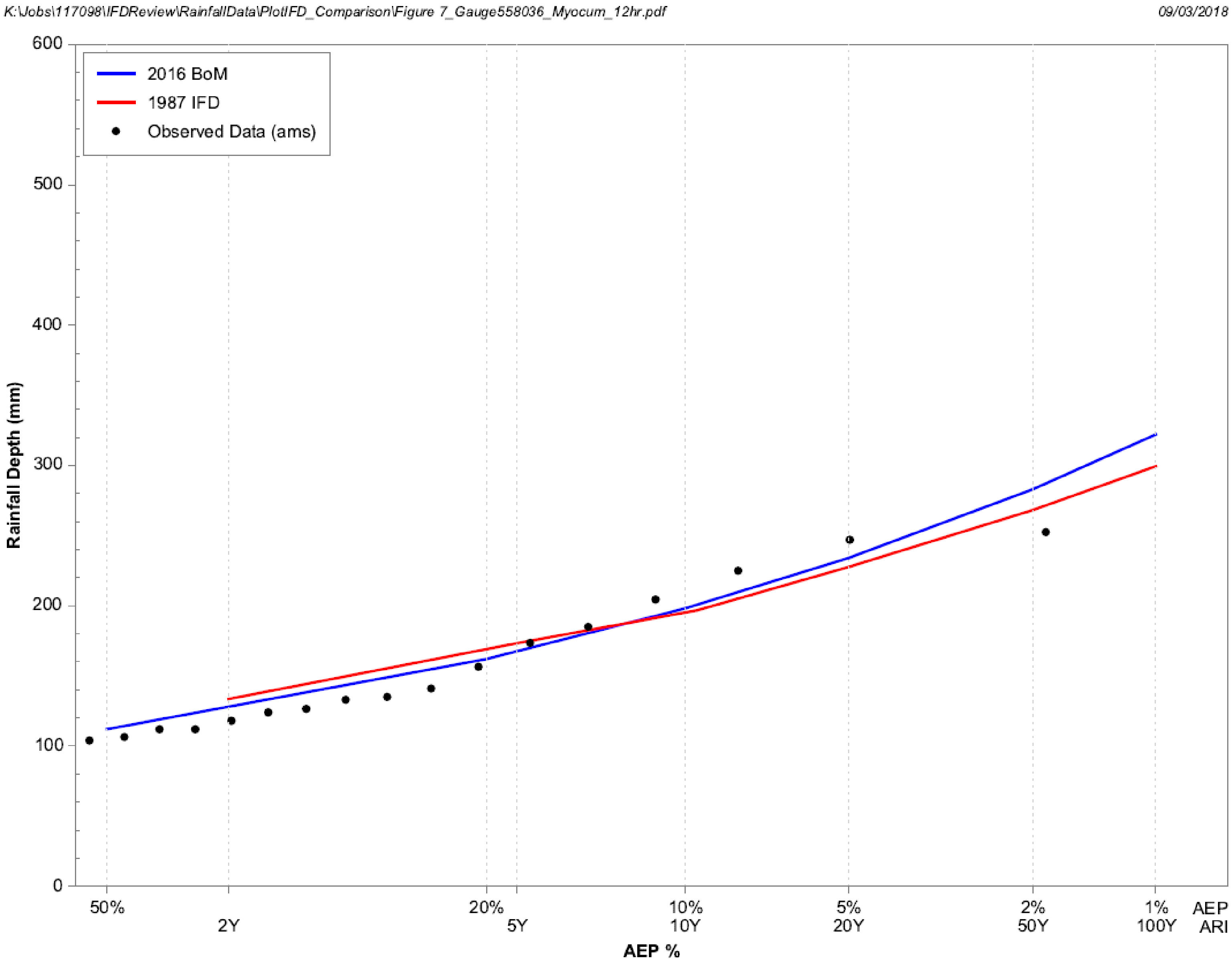

FIGURE 7
PLUVI (12 HOUR DURATION)
IFD & AMS COMPARISON
GAUGE 558036 - MYOCUM

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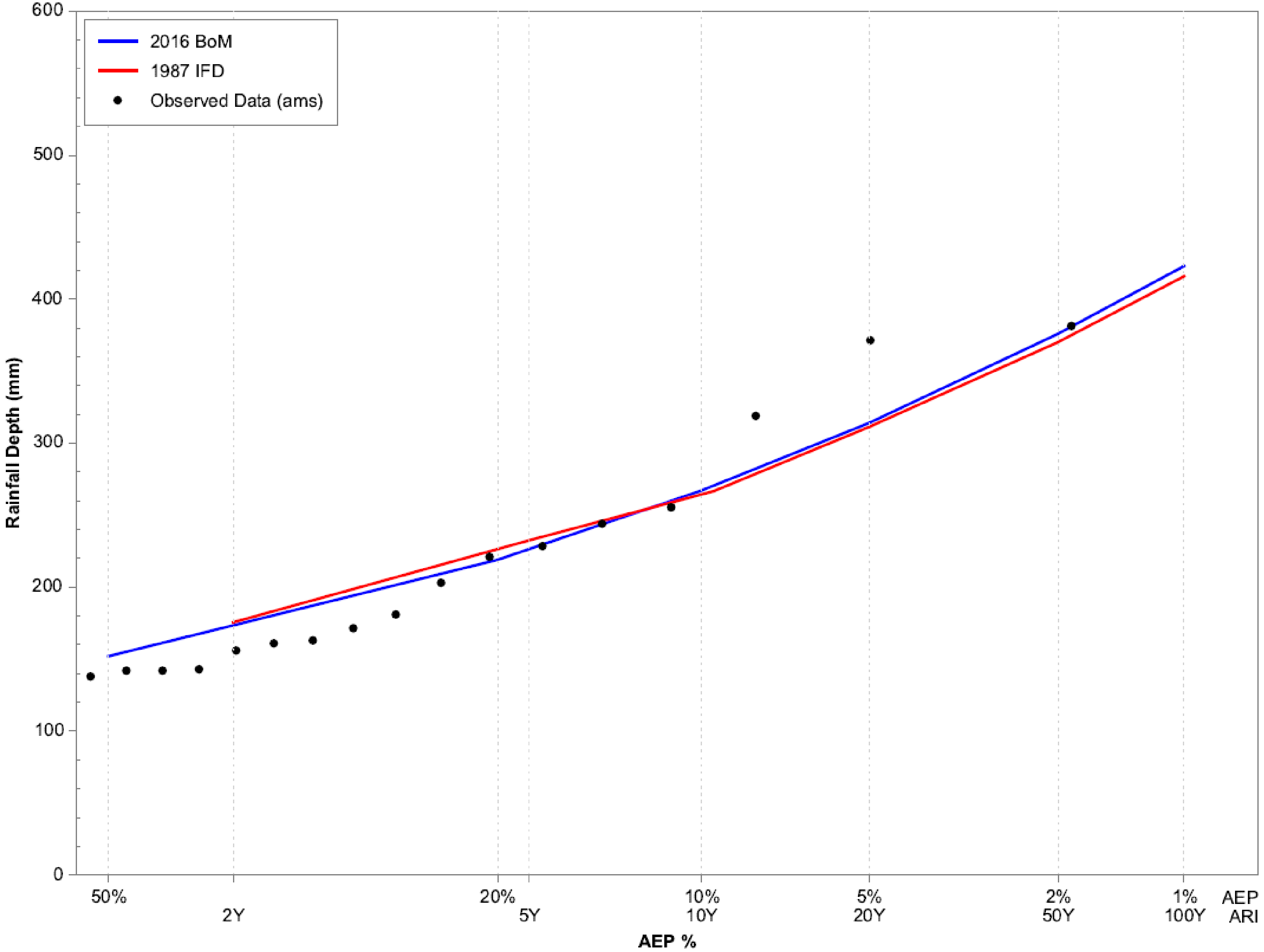

FIGURE 8
PLUVI (24 HOUR DURATION)
IFD & AMS COMPARISON
GAUGE 558036 - MYOCUM

3.3.3. Huonbrook Gauge

Figure 9 plots the 24 hour AMS for the Huonbrook gauge against the Main Arm 24 hour AMS. This figure shows that while there is a strong correlation in rainfall depths between these gauges, there are three outliers where the Huonbrook gauge appears to have failed. Further investigation confirmed the Huonbrook pluviometer failed for the rainfall events of February 1991, February 2001 and January 2012 (within the water years of 1990, 2000 and 2011).

Critical durations for the North Byron catchment are the 12 hour and 24 hour rainfall durations and therefore this section is focusing on these durations. Figure 10 plots the 12 hour AMS for Huonbrook and Main Arm gauges. While the relationship between the two gauges for the 12 hour storm duration is weaker than the 24 hour duration, the correlation is still strong enough to justify a relationship between Huonbrook and Main Arm.

To ensure the rainfall frequency analysis includes all large rainfall events, particularly for the critical durations, a linear relationship between rainfall depths at Main Arm and Huonbrook has been developed for each rainfall duration. The quality control process undertaken as part of the IFD revision project (Reference 8) adopted a similar approach for the disaggregation of accumulated daily rainfall totals. For daily rainfall gauges which had an accumulated period of data, the project took the daily rainfalls from the three nearest gauges within 3km. The daily rainfall at the gauge site of interest was then estimated by weighting the gauges based on distance. This project (Reference 8) shows there is justification to use gauges nearby to estimate rainfall depths provided there is a good correlation between the gauges.

It is important to recognise that the spatial relationship between gauges becomes weaker the shorter the rainfall duration. Appendix C-6 plots the AMS for Main Arm and Huonbrook for each rainfall duration. These figures show that while there is general agreement between the two gauges, the correlation becomes weaker for these shorter durations. However, while estimating rainfall depths for the 1991, 2001 and 2011 events is not as accurate as having recorded data, it is preferred over removing these years from the analysis and is considered conservative. Appendix C-6 plots the AMS for Main Arm and Huonbrook for each rainfall duration. Table 5 shows the adopted rainfall depths for Huonbrook for years 1990 and 2000 for the 12 hour and 24 hour storm durations.

Table 5: The estimated rainfall depths based on Main Arm for the 12 hour and 24 hour rainfall durations for the Huonbrook gauge.

Year	12h		24h	
	Main Arm	Estimated Huonbrook	Main Arm	Estimated Huonbrook
1990	176.5	190.89	198	225.83
2000	267	273.56	380.5	413.01
2011	209	220.58	231.5	260.19

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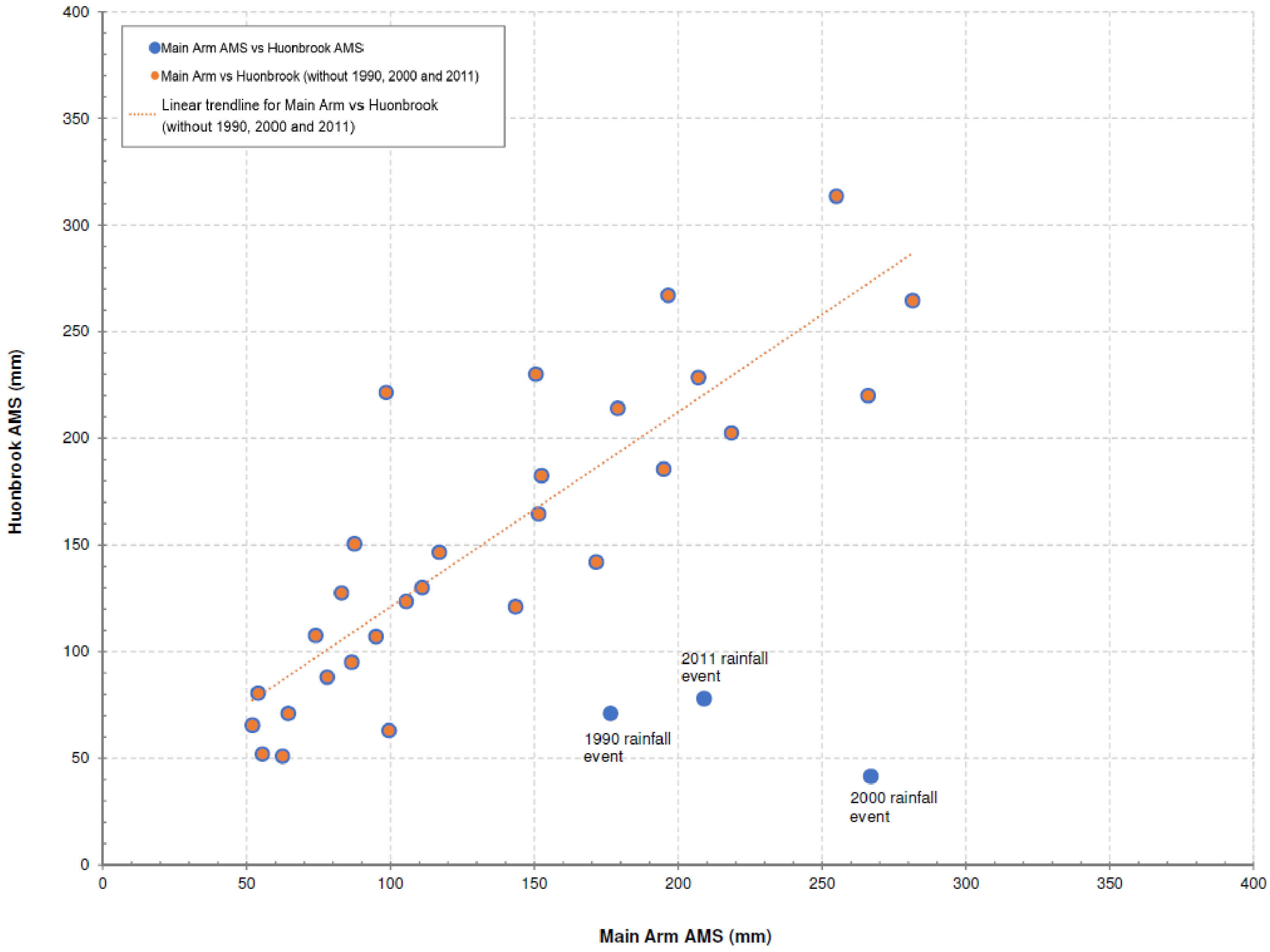

FIGURE 9
PLUVI (12 HOUR DURATION)
MAIN ARM & HUONBROOK AMS

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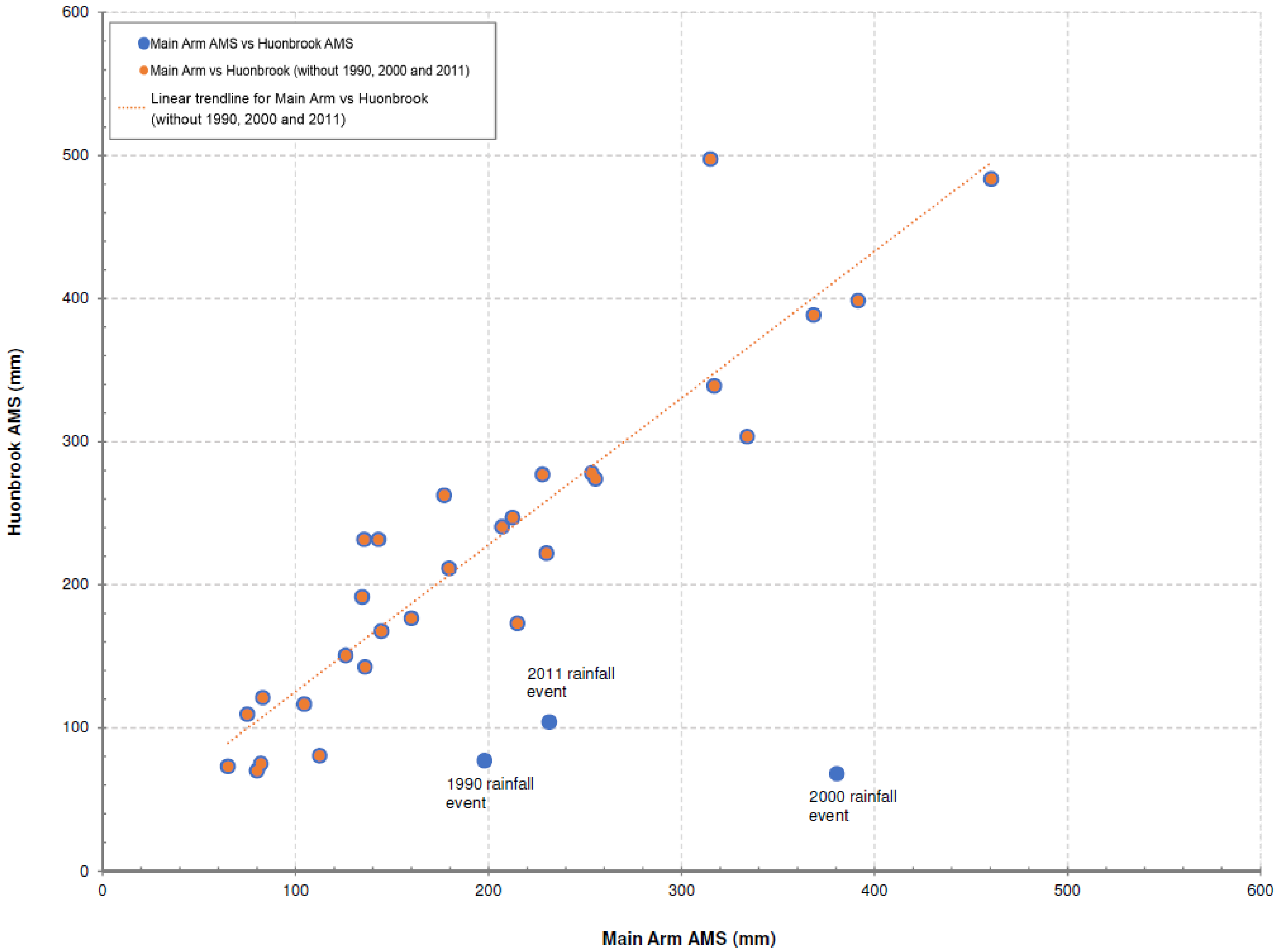


FIGURE 10
PLUVI (24 HOUR DURATION)
MAIN ARM & HUONBROOK AMS

The comparison to the 2016 and 1987 IFDs for the at-site gauge data for Huonbrook can be seen in Figure 11 and Figure 12. For both the 12 hour storm duration and 24 hour storm duration the comparison shows the 2016 IFD represents the at-site gauge data well. There is a slight underestimation in the 24 hour storm duration between the 20% AEP and 5% AEPs. Appendix C-4 shows the comparison between the 2016 and 1987 IFDs to the at-site gauge data for the remaining durations and shows that generally there is no trend for the 2016 IFDs to either over or underestimate the rainfall.

Table 6 compares the at-ste rainfall frequency analysis to the 2016 IFD and highlights where differences between the two are greater than +/-10% (orange cells) and greater than +/-30% (blue cells). A key point here, as included above, is that this table compares two statistical models and is not a comparison between the actual at-site rainfall and the 2016 IFD. There are 15 instances where the difference is greater than +/-10% and only two occurances where the difference between the two models is greater than +/-30%. Similar to the Myocum gauge, Huonbrook only has 32 years worth of data and fitting a distribution to data of this length brings in a high level of uncertainty. Given this, it is expected there will be differences in the two models, particularly for the larger AEP events.

Figure 13 and Figure 14 provide a comparison to the 2016 and 1987 IFDs for the at-site gauge data both with and without substituting 1990, 2000 and 2011 with the estimated rainfalls in Table 5. As shown in these figures, the original rainfall frequency analysis is not substantially different to the rainfall frequency analysis using substituted rainfall events for the years 1990, 2000 and 2011. As the assessment is looking to understand if the IFDs represent the at-site gauge data well and the focus of this report is on the critical durations, the Huonbrook at-site data is considered fit for purpose. The general agreement between the 2016 IFDs and the at-site gauge data shown in Appendix C-4 and Table 6 shows that the 2016 IFD do accurately represent the Huonbrook gauge data.

Table 6: Comparison between the fitted GEV distribution for at-site gauge data and 2016 ARR IFDs for the Huonbrook gauge.

		Rainfall depth (mm) for AEPs (1 in x)					
Duration		2	5	10	20	50	100
0.5hr	558049	32.4	41.1	46.5	51.5	57.6	62
	2016 IFD	29.4	38.8	45.4	51.9	60.7	67.5
1hr	558049	43.3	55.8	64.4	72.7	83.8	92.4
	2016 IFD	39.3	53.0	62.8	72.7	86.7	97.9
2hr	558049	63.3	81.2	90.9	98.8	107.4	112.9
	2016 IFD	52.7	73.5	88.6	104.0	127.0	145.0
3hr	558049	75	96.7	107.8	116.6	125.7	131.2
	2016 IFD	63.6	90.4	110.0	131.0	160.0	185.0
6hr	558049	107.9	143.7	161.6	175.4	189.5	197.8
	2016 IFD	90.7	133.0	164.0	197.0	242.0	279.0
12hr	558049	154.6	221.8	259.2	290.7	325.7	348.4
	2016 IFD	133.0	198.0	246.0	296.0	362.0	414.0
24hr	558049	216.5	322.8	389.3	450.4	525.6	579.3
	2016 IFD	193.0	290.0	359.0	429.0	516.0	582.0
36hr	558049	256.5	384.5	466.9	544.1	641.7	713.1
	2016 IFD	235.0	351.0	433.0	514.0	613.0	687.0
48hr	558049	280.3	420.1	510.5	595.8	703.9	783.4
	2016 IFD	266.0	395.0	485.0	574.0	680.0	760.0
72hr	558049	320.5	479.8	585.1	685.8	816	913.4
	2016 IFD	307.0	453.0	553.0	651.0	769.0	856.0
96hr	558049	342.5	517.6	637.3	754.8	911.2	1031.6
	2016 IFD	333.0	490.0	596.0	701.0	826.0	918.0
120hr	558049	361.9	547.1	671.4	791.8	949.4	1068.9
	2016 IFD	350.0	515.0	627.0	737.0	869.0	966.0

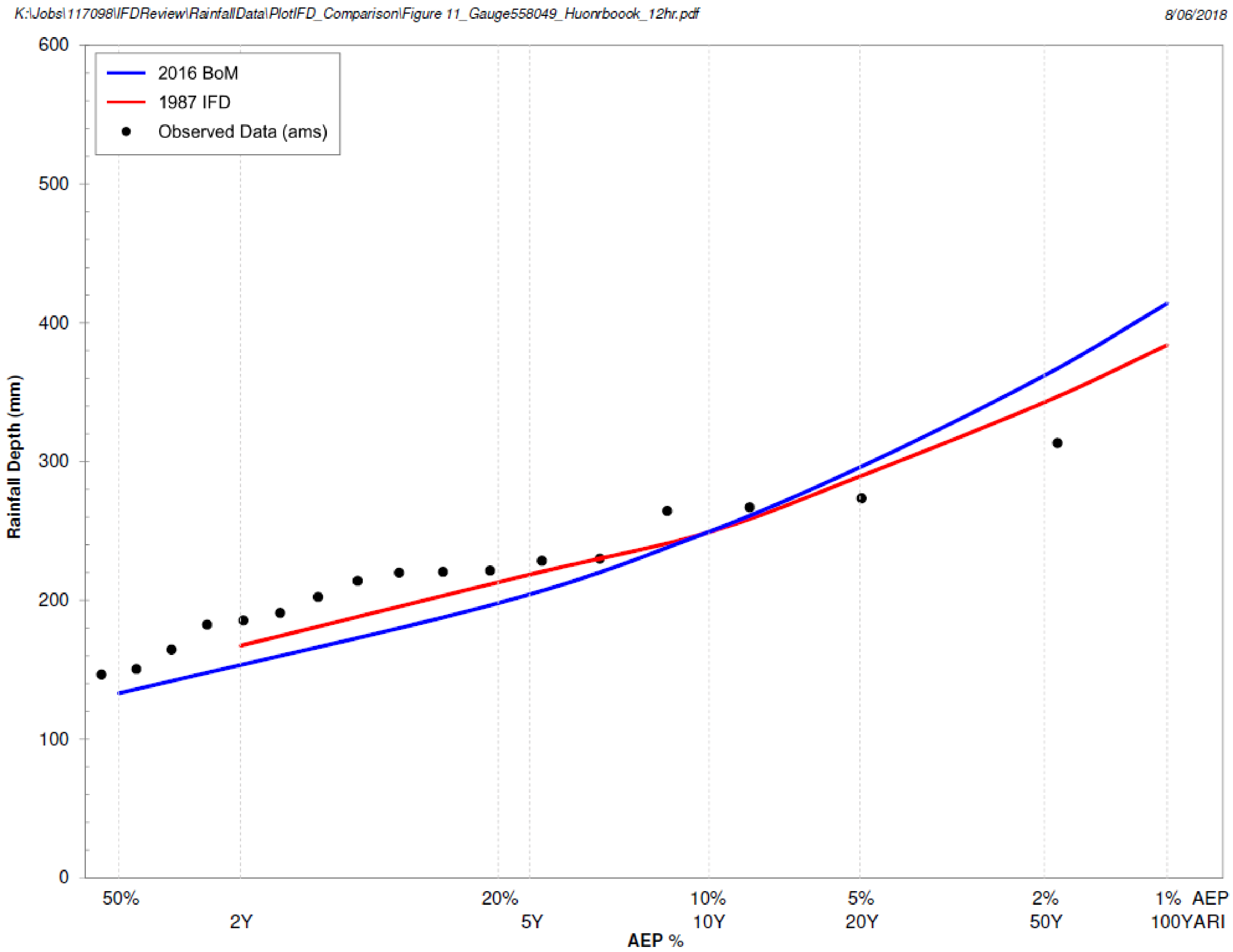
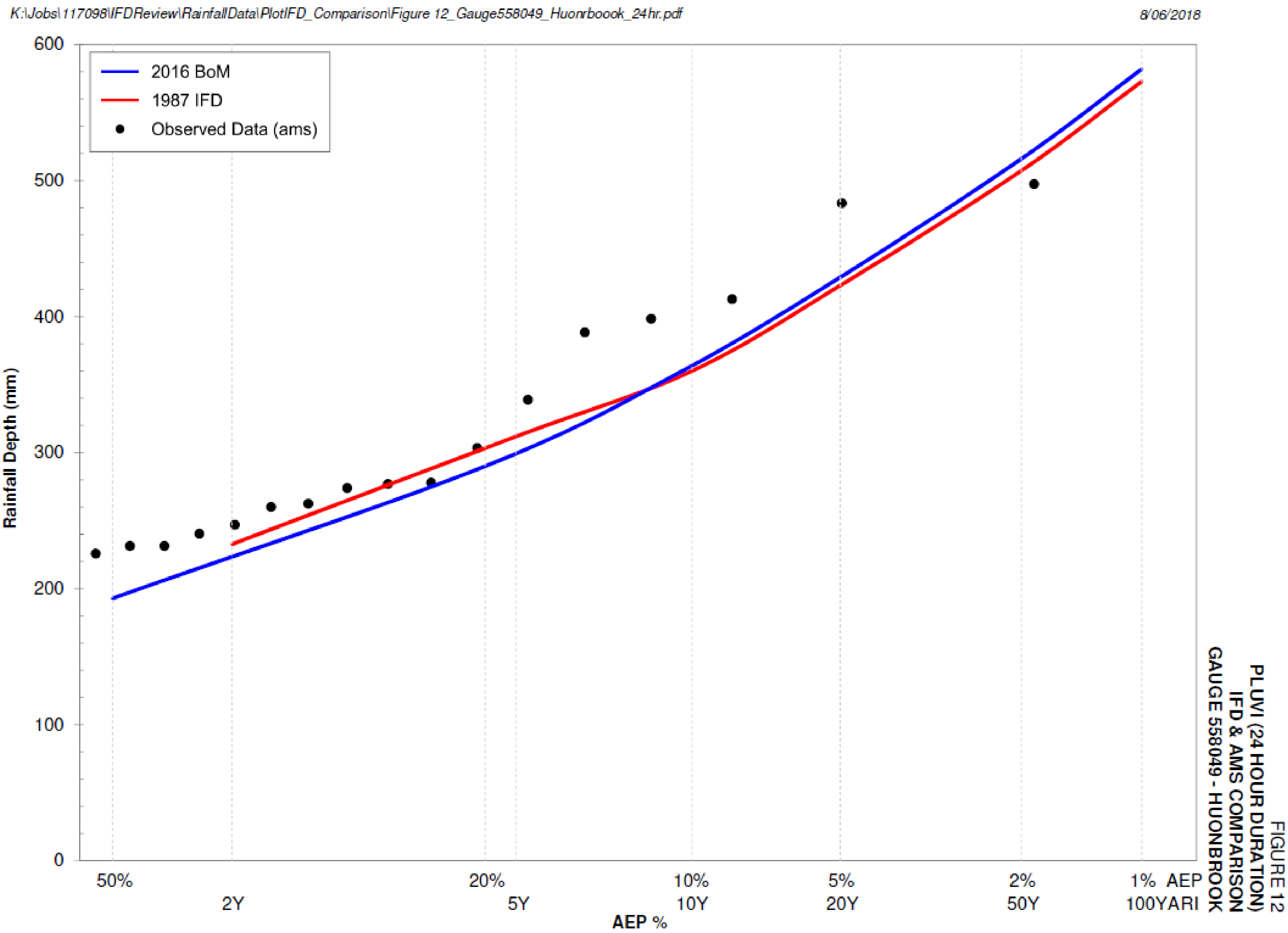


FIGURE 11
PLUVI (12 HOUR DURATION)
IFD & AMS COMPARISON
GAUGE 558049 - HUONBROOK


K:\Jobs\117098\IFDReview\RainfallData\PlotIFD_Comparison\Figure 12_Gauge558049_Huonrboook_24hr.pdf
8/06/2018
2016 BoM
1987 IFD
Observed Data (ams)
Rainfall Depth (mm)
600
500
400
300
200
100
0
50%
2Y
20%
5Y
10%
10Y
5%
20Y
2%
50Y
1% AEP
100YARI
AEP %
FIGURE 12
PLUVI (24 HOUR DURATION)
IFD & AMS COMPARISON
GAUGE 558049 - HUONBROOK

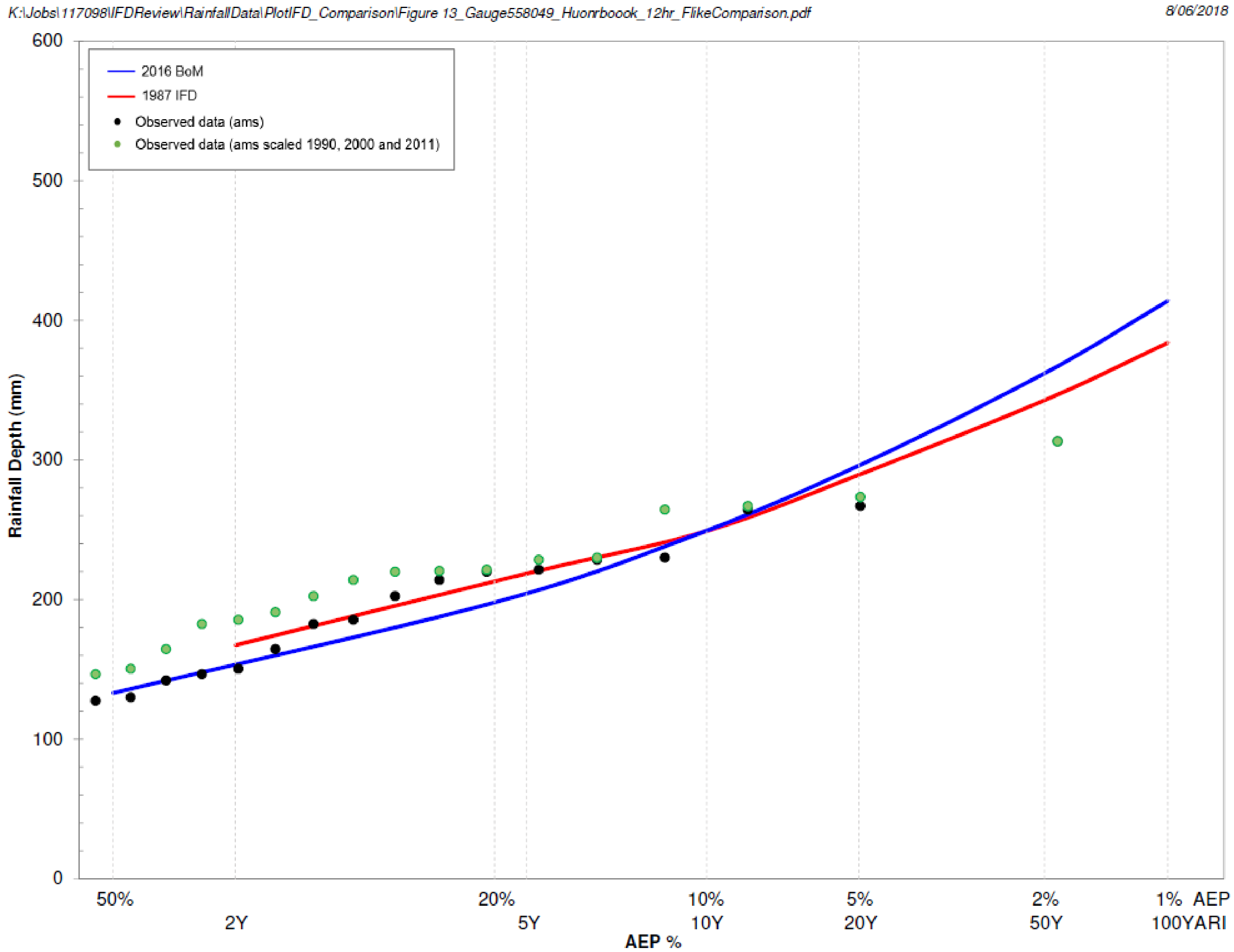


FIGURE 13
PLUVI (12 HOUR DURATION)
IFD & AMS COMPARISON
GAUGE 558049 - HUONBROOK

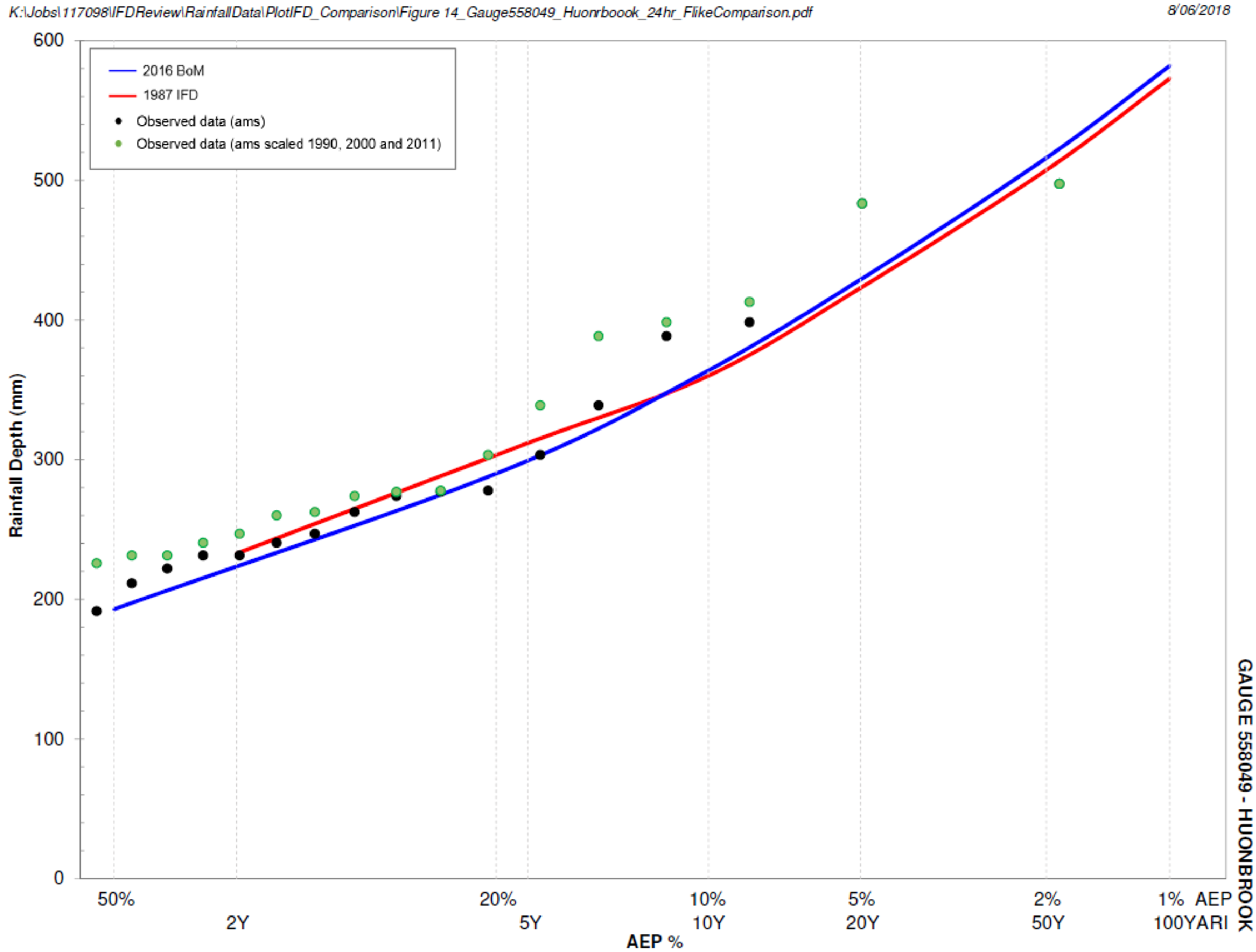


FIGURE 14
PLUVI (24 HOUR DURATION)
IFD & AMS COMPARISON
GAUGE 558049 - HUONBROOK

3.3.4. Federal Post Office Gauge

The 2016 ARR IFDs provide a fit-for-purpose representation of the at-site gauge data for Federal Post Office. The AMS for the Federal Post Office was plotted against the 2016 and 1987 IFDs, as seen in Figure 15 and Figure 16.

The 2016 IFD provides an extremely good fit for the 12 hour storm duration, whereas the 1987 IFD underestimates rainfall for the larger AEP events. However, the 24 hour duration shows the 1987 IFD agrees better with the at-site data. Appendix C-4 includes plots comparing the IFDs to the at-site gauge data for other storm durations assessed. While the 1987 IFD does sometimes provide a better fit, the 2016 IFD consistently fits better. Figure C47 and Figure C48 of Appendix C-4 are a good example of this. Neither IFD shows a trend for over or underestimation of rainfall depths.

Table 7: Comparison between the fitted GEV distribution for at-site gauge data and 2016 ARR IFDs for Federal Post Office gauge.

Rainfall depth (mm) for AEPs (1 in x)							
Duration		2	5	10	20	50	100
0.5hr	058072	27	39.4	48.6	58.2	71.9	83.3
	2016 IFD	29.8	39.5	46	52.4	60.8	67.2
1hr	058072	40.3	60.4	74.7	89.2	109.2	125.2
	2016 IFD	39.9	53.8	63.4	72.9	86.2	96.6
2hr	058072	56.5	86.9	109.1	132.2	164.9	191.7
	2016 IFD	53.1	73.1	87.5	102	123	139
3hr	058072	68.1	102.8	127.9	153.5	189.3	218.2
	2016 IFD	63.1	88.2	106	125	152	173
6hr	058072	87.4	131.9	165.7	201.9	254.8	299.5
	2016 IFD	86.4	124	151	179	218	249
12hr	058072	116.2	171.6	209.2	246	294.6	331.8
	2016 IFD	120	174	214	254	307	350
24hr	058072	169.4	241.1	280.7	313.7	350.2	373.6
	2016 IFD	166	242	295	349	417	469
36hr	058072	191.7	281	333.2	378.7	431.4	466.9
	2016 IFD	197	286	347	408	484	541
48hr	058072	208.7	310.6	372.6	428.3	495.2	541.8
	2016 IFD	220	318	384	448	530	590
72hr	058072	235.3	352.8	425.5	491.6	572.1	628.9
	2016 IFD	251	360	432	502	590	655
96hr	058072	266.9	392.9	465.2	527.2	598.1	645
	2016 IFD	270	386	462	535	629	697
120hr	058072	278.2	411.8	488.5	554.2	629.4	679.2
	2016 IFD	284	404	484	560	656	727

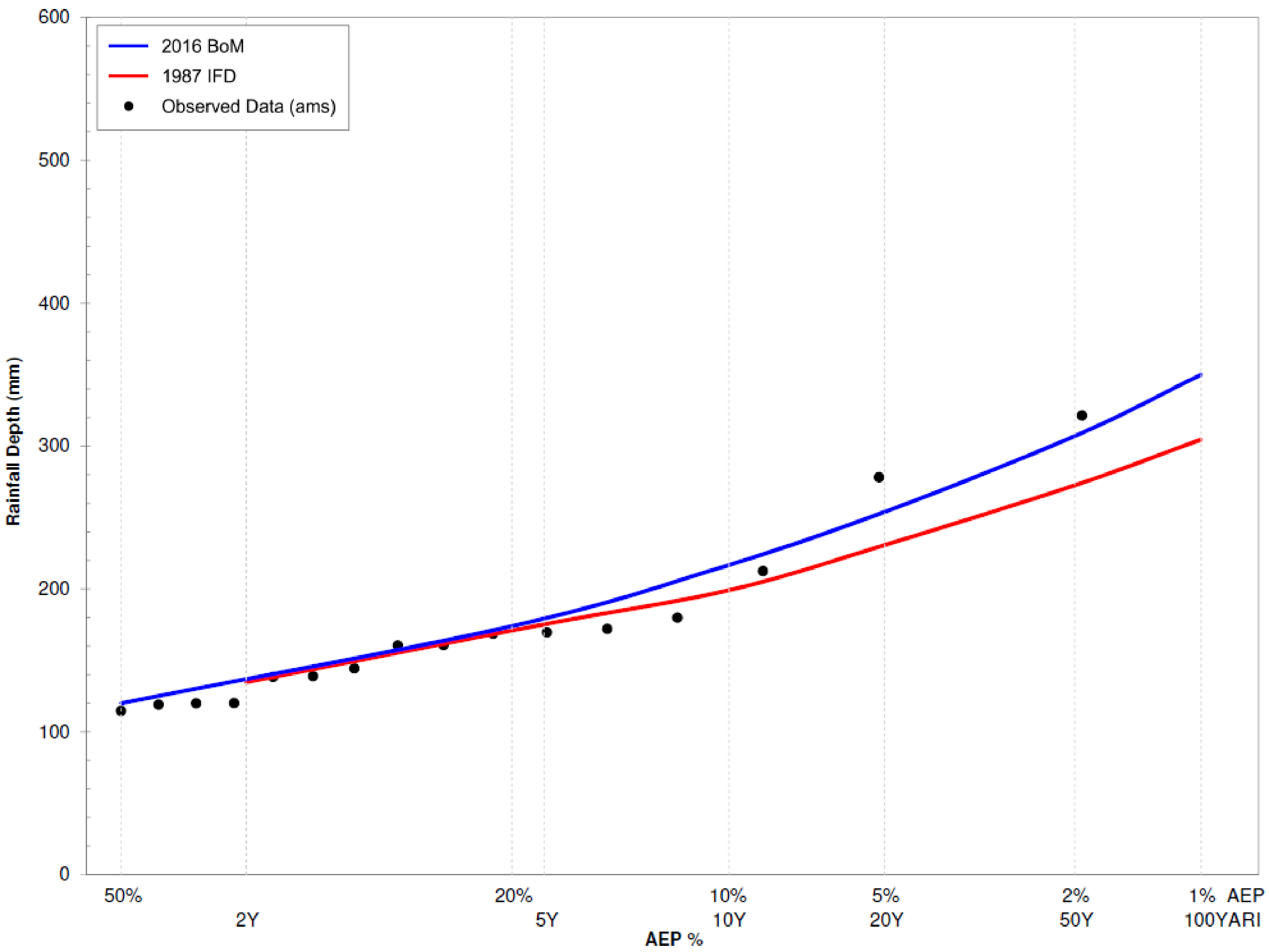


FIGURE 15
PLUVI (12 HOUR DURATION)
IFD & AMS COMPARISON
GAUGE 58072 - FEDERAL POST OFFICE

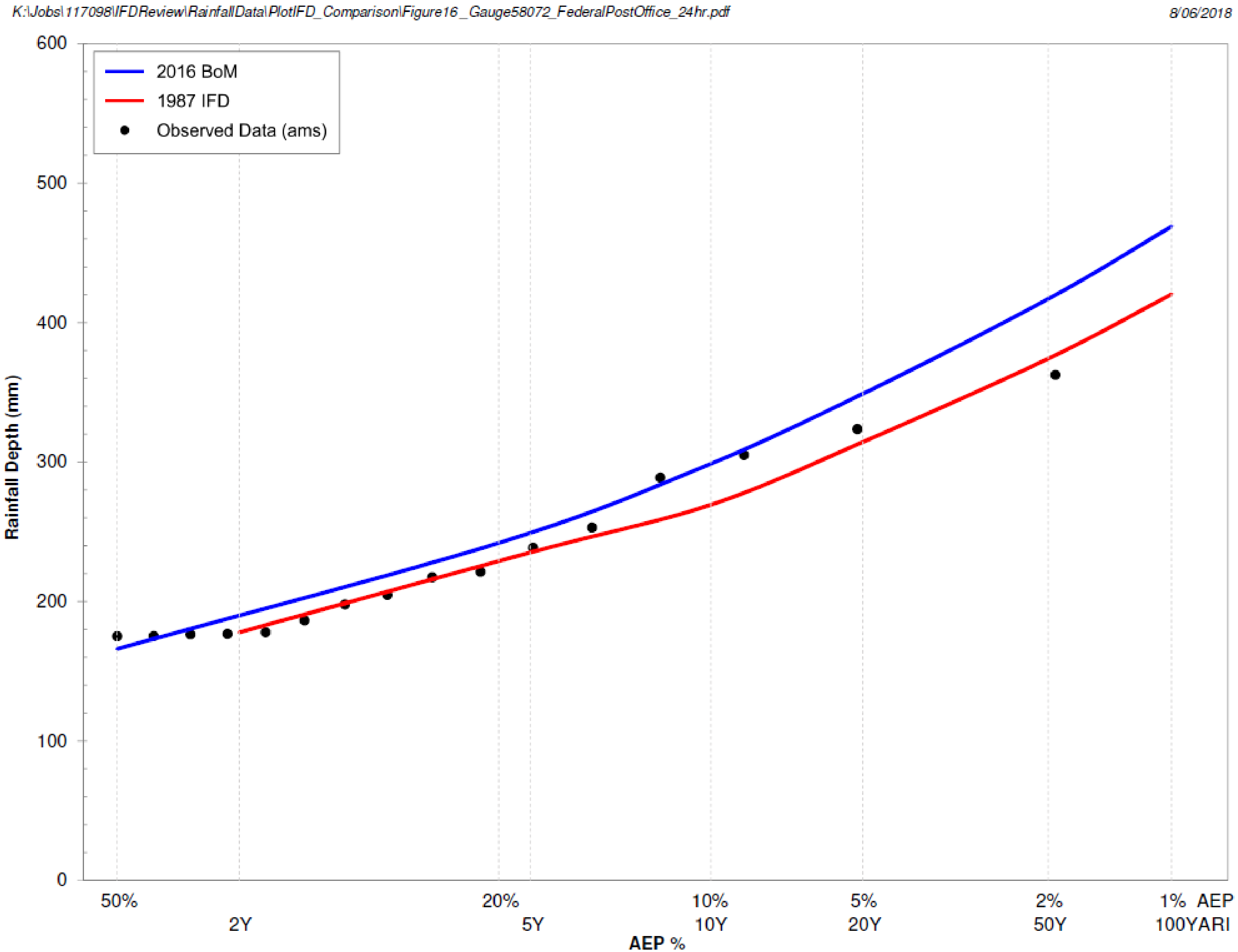


FIGURE 16
PLUVI (24 HOUR DURATION)
IFD & AMS COMPARISON
GAUGE 58072 - FEDERAL POST OFFICE

4. CONCLUSIONS

As outlined in the Technical Brief, the purpose of the Rainfall Frequency Analysis was to identify if there was significant bias between the at-site gauge data and the 2016 ARR IFDs and provide a recommended approach for the North Byron Floodplain Management Study and Plan. The assessment focused on identifying spatial trends of over or underestimation. The above sections describe the approach used in this analysis, provide some context around the 2016 IFDs and outline the results.

While the 2016 IFDs are consistently lower than the 1987 IFDs, the 2016 IFDs agree better with the observed at-site data. It could be argued adopting the higher 1987 IFDs would be a conservative approach, however it is not recommended that factors of conservatism are applied at the design rainfall stage. The aim of the work is to provide the best estimate of current day rainfall depths. Other factors can be applied at a later stage to allow for uncertainty in estimation techniques.

Prior to the development of the 2016 IFDs, the 1987 IFDs were the best available estimates. While the 2016 IFDs have their limitations, they are an improvement from the 1987 IFDs. The results of this analysis demonstrate there is no evidence to continue with the 1987 IFDs, and the 2016 IFDs provide a better fit for the gauges in the North Byron catchments.

The analysis concluded the following:

- There is no evidence of the 2016 IFDs significantly over or underestimating rainfall data across the study area (Section 3.3).
- In general, the 2016 IFDs provide a good fit when compared to the at-site gauge data. There are occurrences of the 2016 IFDs marginally overestimating rainfall depths, particularly for rarer storm events. However, due to the record length of the gauges and the regionalisation approach used for the 2016 IFDs there is more confidence in the 2016 IFD estimates (Section 2.2and Section 3.3).
- The 2016 IFDs are a significant improvement on the 1987 IFDs and overall provide a better representation of the gauge data (Section 3.3).

The findings above conclude the 2016 IFDs provide a good fit against the at-site rainfall data. However, a move towards the 2016 ARR is not limited to the adoption of the 2016 IFDs. Along with the revised IFDs, the 2016 ARR introduces new flood modelling techniques. ARR (Reference 2) discusses the changes between the 1987 and 2016 ARR versions in detail, however the key changes relating to this project are summarised below:

- Revised IFDs (as discussed in detail throughout this report)
- Areal Reduction Factors developed based on Australian data and available for all more durations
- Changes in initial and continuing losses
- Ensemble of 10 temporal patterns in replacement of the traditional single burst temporal pattern
- A move towards the Monte Carlo approach to flood modelling.

While the new ARR is considered best-practice it is important to understand how the difference in 1987 and 2016 ARR methodologies compare to the recorded data within the study area. The above differences should be considered prior to adopting the 2016 IFDs and additional investigation is required to understand the suitability of the 2016 ARR. It is recommended comparing the hydrologic results using the 2016 IFDs and ARR methodology to the Flood Frequency Analysis undertaken in the Flood Study (Reference 1).

5. REFERENCES

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3. Bureau of Meteorology, Intensity-Frequency-Durations (http://www.bom.gov.au/water/designRainfalls/ifd/index.shtml) February 2018

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