Public Works
Manly Hydraulics Laboratory

NSW NORTH COAST FLOOD SUMMARY JANUARY-MARCH 2013

Report MHL2202
May 2013

prepared for
Office of Environment and Heritage

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A division of the Department of Finance and Services

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NSW North Coast Flood Summary
January–March 2013

Report MHL 2202
May 2013

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Cover photograph: Grafton, Clarence River, 8.10 am, 29 January 2013

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Foreword

This report was commissioned by the NSW Office of Environment and Heritage (OEH) to summarise the January, February and March 2013 flood events in the north and mid-north coast rivers of New South Wales. OEH manages an extensive data network in the NSW coastal zone. The coastal data network is operated and maintained by NSW Public Works' Manly Hydraulics Laboratory (MHL) under an annual contract to OEH.

Data analysis and reporting was undertaken by Amity Alexander, Martin Riley and Erin Alley of MHL. The report was overseen by Martin Fitzhenry from the Environment Programs Services Branch, OEH.

An electronic copy of this report can be downloaded at www.mhl.nsw.gov.au.

Summary

In January 2013, ex-tropical cyclone Oswald brought heavy rainfall and damaging wind gusts to the north and mid-north coast of NSW. This event resulted in widespread flooding of the area, with major flooding recorded in the Richmond and Clarence river regions. Following this event, the north and mid-north coast experienced two subsequent flood events. The February event resulted in major flooding in the Clarence, Bellinger and Macleay river regions, whilst the March event resulted in moderate to minor flooding across all regions.

During this extended flood period, MHL staff were able to monitor the situation via their real-time data network and were able to provide clients and the public with real time access to rainfall, wave, wind and water levels via customised webpages and MHL's public webpage at www.mhl.nsw.gov.au. MHL deployed multiple field teams in the flood-affected areas to obtain flood status checks and to be available to remedy any system failures.

During the flood events, the Bureau of Meteorology (BoM) used water level and rainfall data, Quantitative Precipitation Forecasts (QPF) and radar information to generate predicted water levels at warning locations on the flood-affected rivers. The water level predictions were used by the BoM to issue flood watches, flood warnings and flash flood warnings. MHL staff also provided data and advice to the SES.

This report presents water level, wave and rainfall hydrometric data collected during the January to March 2013 flood events in the north and mid-north coast of NSW. Data collection, storage and presentation were undertaken by MHL for the Office of Environment and Heritage.

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1. Introduction

In January 2013, ex-tropical cyclone Oswald brought heavy rainfall and damaging wind gusts to the north and mid-north coast of NSW. Figure 1.1 presents atmospheric pressure charts and radar rainfall intensity data from the Grafton radar during this event. This weather system resulted in widespread flooding of the area, with major flooding recorded in the Richmond and Clarence river regions. The majority of heavy rainfall occurred between 24 and 28 January 2013. In Grafton, the Clarence River peaked at a new record height of 8.09 m AHD on 29 January 2013.

The weather system resulted in damaging wind gusts, with several buildings in Ballina suffering significant roof damage. Figure 1.5 shows the wind rose from the Bureau of Meteorology's Ballina Airport automatic weather station during the event. During the January event the wind was predominantly from the north-east as the weather system moved down the NSW coastline.

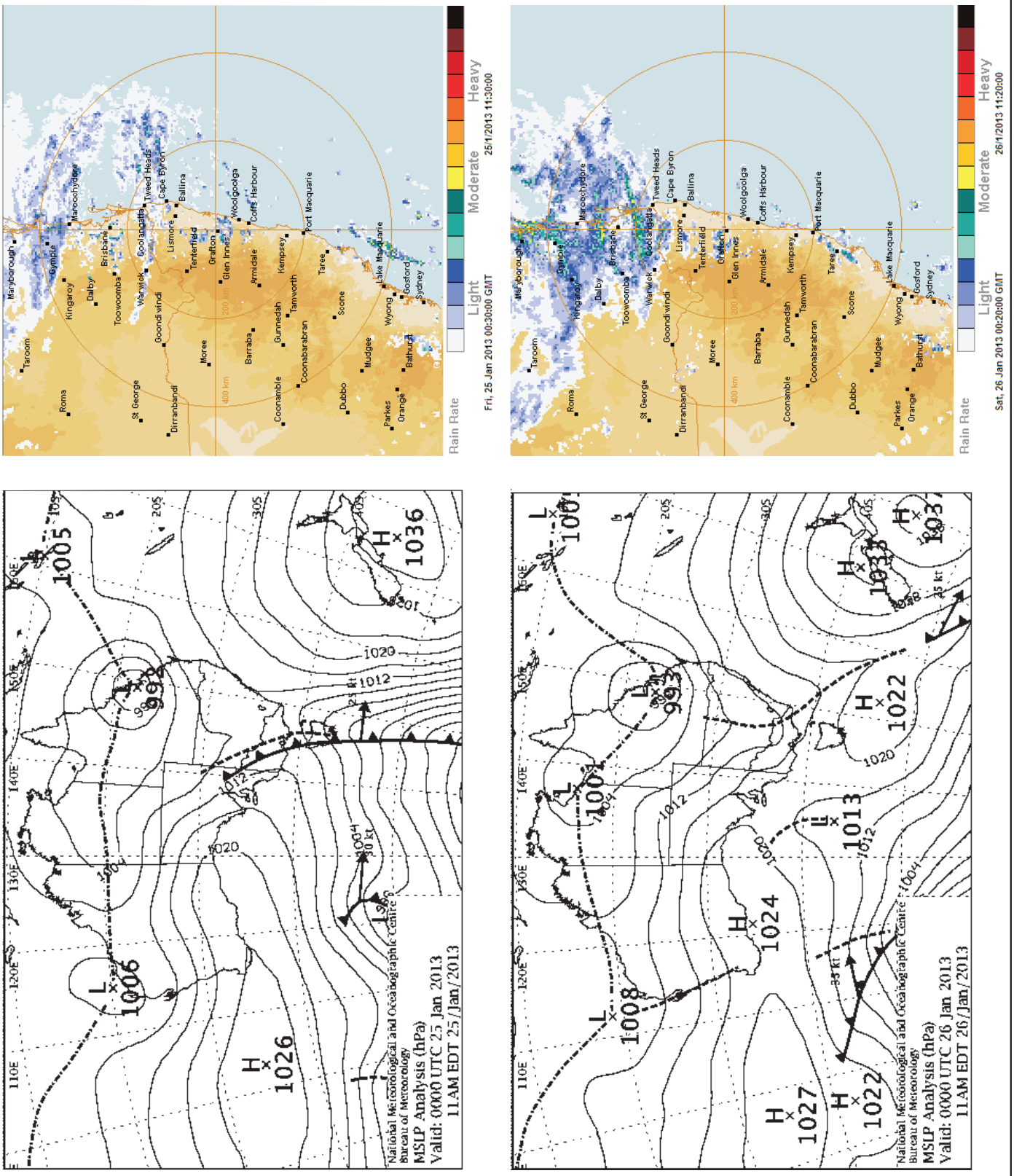
Following this event, the north and mid-north coast experienced two subsequent flood events in February and March 2013. Figures 1.2 and 1.3 show atmospheric pressure charts and radar rainfall intensity data from the Grafton radar during these events, with the majority of heavy rainfall occurring between 19 and 23 February 2013 and 2 and 3 March 2013. The February event resulted in major flooding in the Clarence, Bellinger and Macleay river regions, whilst the March event resulted in moderate to minor flooding across all regions.

Twenty-two local government areas were declared natural disaster areas as a result of the January and February 2013 storms and flooding. Figure 1.4 shows the rainfall recorded across Australia from 1 January to 31 March 2013.

During the flood events, the monitoring networks of water level recorders and rainfall gauges operated by MHL, on behalf of OEH, were used extensively by the Bureau of Meteorology, SES and local councils to generate flood warnings, emergency response and delivery of services during the event. Rainfall and water level data captured during the events is summarised by river region in Sections 3 to 12 of this report. Station performance during the events is summarised in Appendix A. Photographs taken during the event are presented in Appendix B.

An indicative adjustment of each station datum level to the local Australian Height Datum (AHD) is shown in Appendix C. These adjustments were calculated circa 1990 for MHL by Roger Harvey from NSW Public Works, using tidal harmonic analysis over a tidal epoch. These values should be used with caution, as AHD levels are revised from time to time and improvements to GPS surveying techniques may provide additional refinement.

MHL was commissioned by OEH to prepare a report to summarise the flood events. Maps of the study areas by river regions are found in Sections 3 to 12 of this report.



Source: Australian Bureau of Meteorology 2013

NSW GOVERNMENT Public Works Manly Hydraulics Laboratory	MEAN SEA LEVEL PRESSURE AND GRAFTON RADAR IMAGES 24-28 JANUARY 2013	MHL Report 2202 Figure 1.1a DRAWING 2202-01-01.cdr

Source: Australian Bureau of Meteorology 2013

NSW GOVERNMENT Public Works Manly Hydraulics Laboratory	MEAN SEA LEVEL PRESSURE AND GRAFTON RADAR IMAGES 24-28 JANUARY 2013	MHL Report 2202 Figure 1.1b DRAWING 2202-01-01.cdr

Source: Australian Bureau of Meteorology 2013

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MEAN SEA LEVEL PRESSURE AND GRAFTON RADAR IMAGES 22-23 FEBRUARY 2013

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Figure 1.2a

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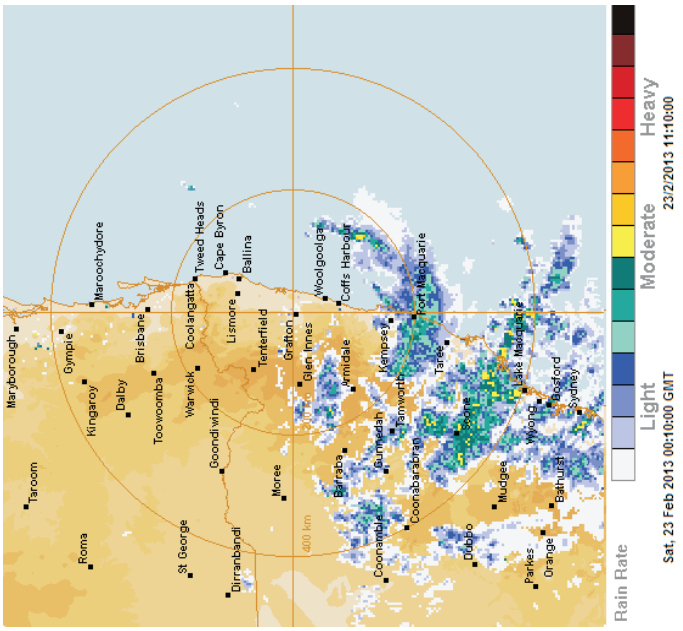
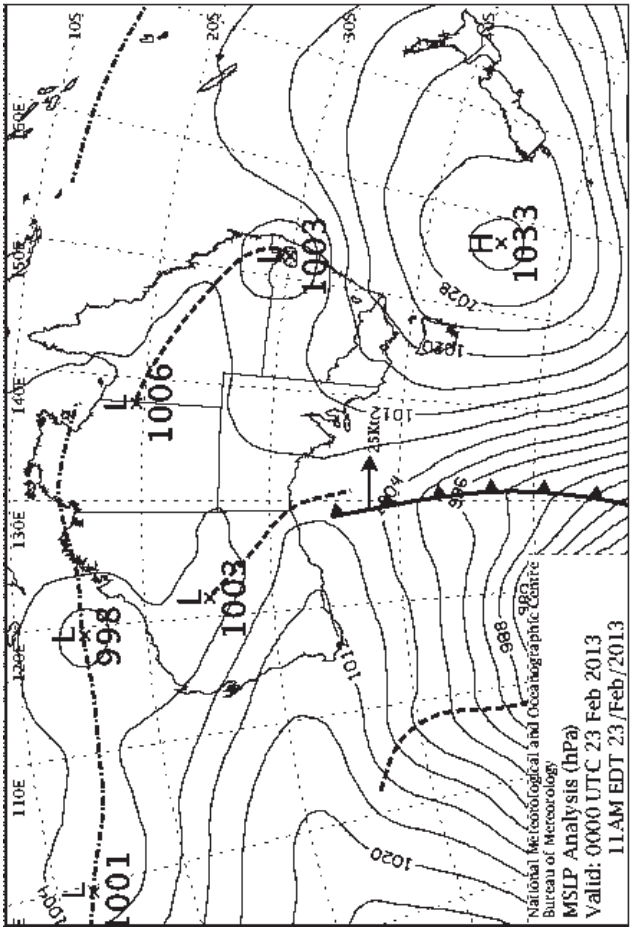
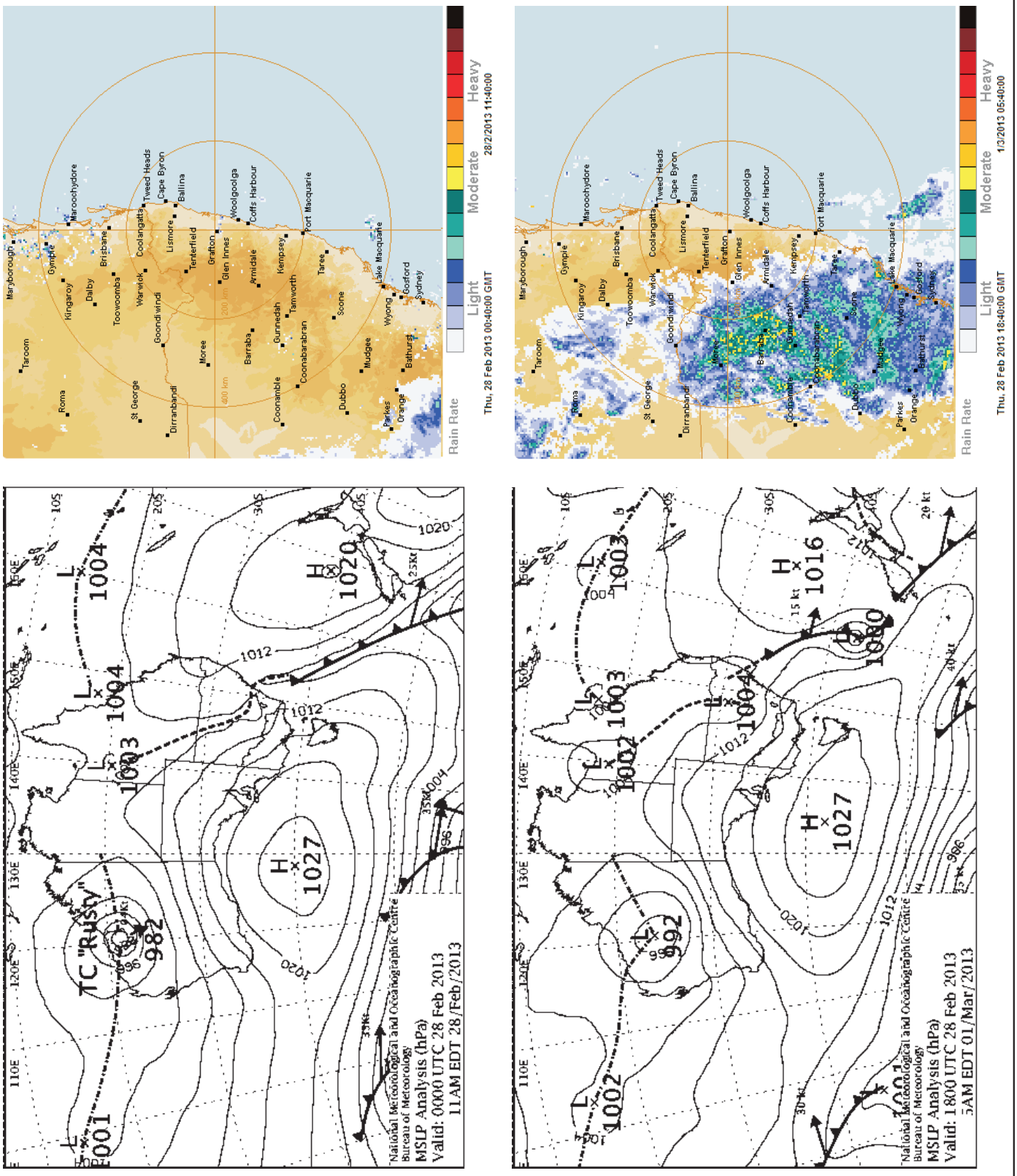




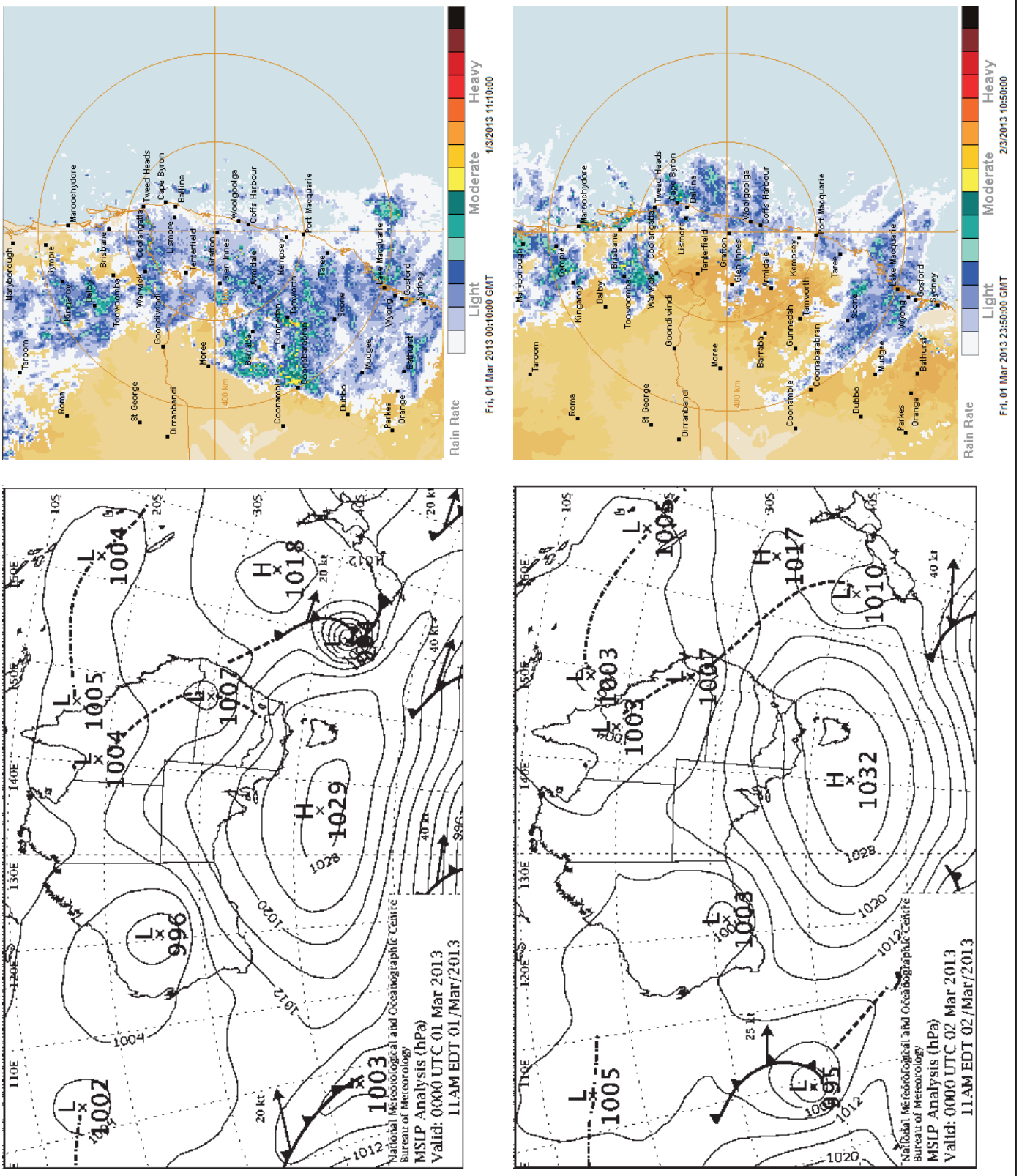
Source: Australian Bureau of Meteorology 2013

NSW GOVERNMENT Public Works Manly Hydraulics Laboratory	MEAN SEA LEVEL PRESSURE AND GRAFTON RADAR IMAGES 22-23 FEBRUARY 2013	MHL Report 2202 Figure 1.2b DRAWING 2202-01-02.cdr



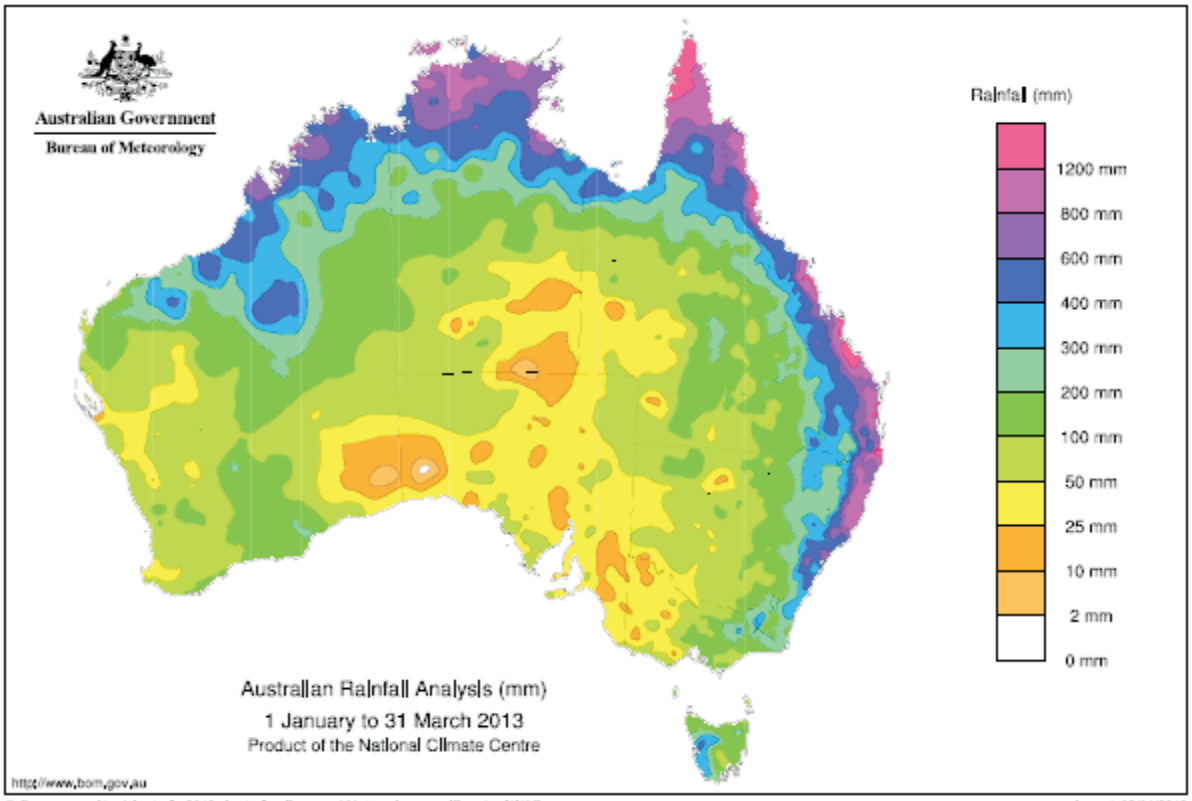
Source: Australian Bureau of Meteorology 2013

NSW GOVERNMENT Public Works Manly Hydraulics Laboratory	MEAN SEA LEVEL PRESSURE AND GRAFTON RADAR IMAGES 28 FEBRUARY-2 MARCH 2013	MHL Report 2202 Figure 1.3a DRAWING 2202-01-03.cdr



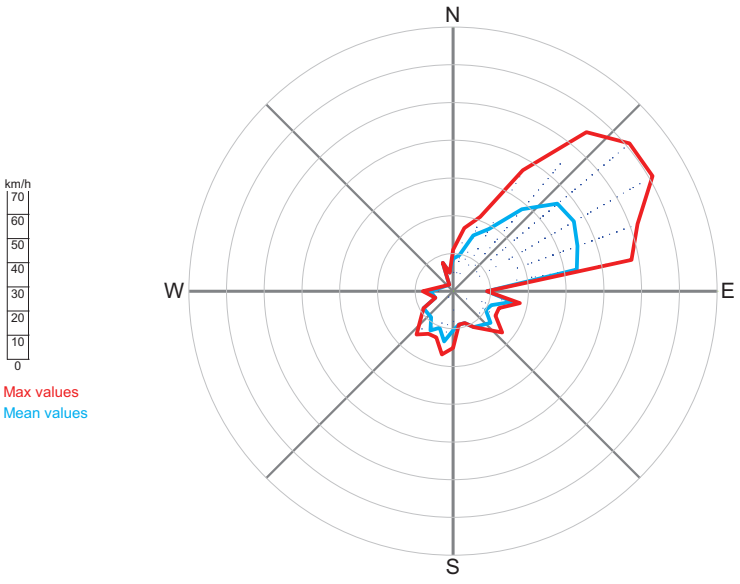
Source: Australian Bureau of Meteorology 2013

NSW GOVERNMENT Public Works Manly Hydraulics Laboratory	MEAN SEA LEVEL PRESSURE AND GRAFTON RADAR IMAGES 28 FEBRUARY-2 MARCH 2013	MHL Report 2202 Figure 1.3b DRAWING 2202-01-03.cdr

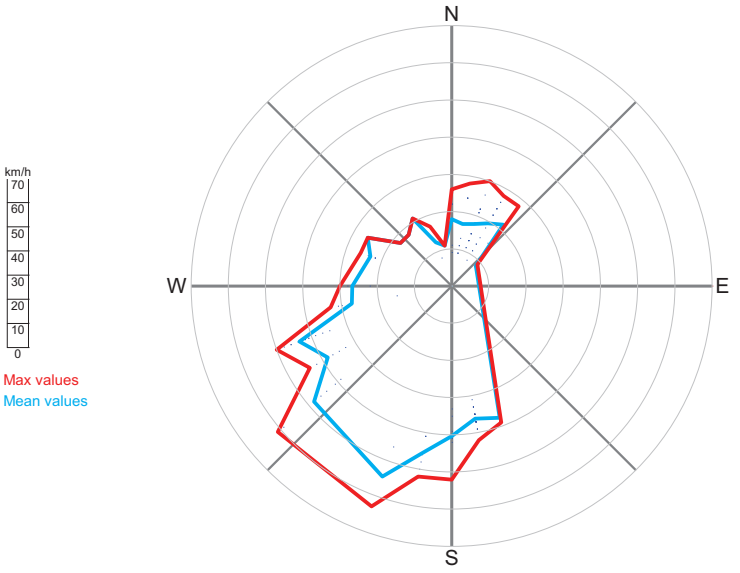


Source: Australian Bureau of Meteorology 2013

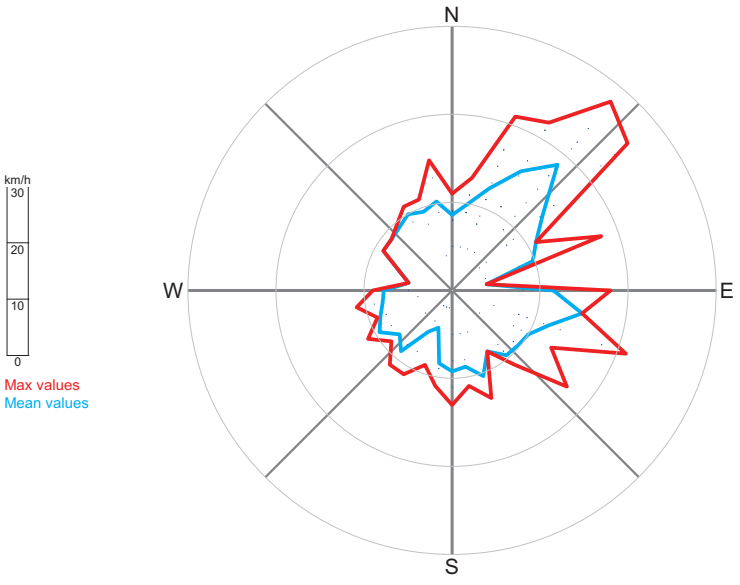
NSW GOVERNMENT Public Works Manly Hydraulics Laboratory	AUSTRALIAN RAINFALL ANALYSIS 1 JANUARY-31 MARCH 2013	MHL Report 2202
		Figure 1.4
		DRAWING 2202-01-04.cdr



24-28 January 2013



22-23 February 2013



28 February-2 March 2013

Source: Australian Bureau of Meteorology 2013

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WIND ROSE FROM BALLINA WEATHER STATION DURING THE THREE EVENTS

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Figure 1.5

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2. Offshore Wave Data

Ocean wave conditions during the flood events along the NSW north coast were recorded by the OEH Byron Bay, Coffs Harbour and Crowdy Head Waverider buoys. Major ocean storm wave events occurred at the time of the January and February 2013 floods.

The ocean storm and flood events in January 2013 were the result of extensive rainfall and extreme wind conditions generated by ex-tropical cyclone Oswald as the system moved south along the Queensland coastline, reaching the NSW north coast on 28 January 2013 (Figure 1.1). The major storm wave conditions in February 2013 were generated by a small, intense low pressure system that developed in the Coral Sea just off the NSW-Queensland border (Figure 1.2). Ocean wave conditions during the March 2013 flood event were relatively mild along the northern rivers coastline and failed to reach the Significant Wave Height storm threshold of 3 m at the Byron Bay Waverider station. However, moderate wave conditions were recorded by the Crowdy Head Waverider buoy during the March 2013 floods.

A summary of the ocean wave conditions recorded during each flood event is presented in Tables 2.1, 2.2 and 2.3. Time history plots of wave height, period and direction for each Waverider buoy station for the period 1 January to 31 March 2013 are presented in Figures 2.1, 2.2 and 2.3.

Table 2.1 Ocean Wave Storm Summary – 24 to 29 January 2013

Wave Conditions	Byron Bay [1]	Coffs Harbour	Crowdy Head
Peak Significant Wave Height (m)	5.00	7.0	5.5
Date and Time of Peak Significant Wave Height (hrs EST)	0000 28/01/2013	1900 28/01/2013	2100 28/01/2013
Peak Maximum Wave Height (m)	8.17	12.6	10.4
Spectral Peak wave period at storm peak (secs)	10.3	10.8	11.5
Wave Direction at Storm Peak (º TN)	92	63	87
Storm Duration for Hsig greater than 4 m (hrs)	3	42	27
Return Period for Storm Peak Hsig (yrs)	Not applicable	15	1.4

[1] Full duration of storm not recorded by the Byron Bay Waverider station – buoy adrift on 28 January 2013

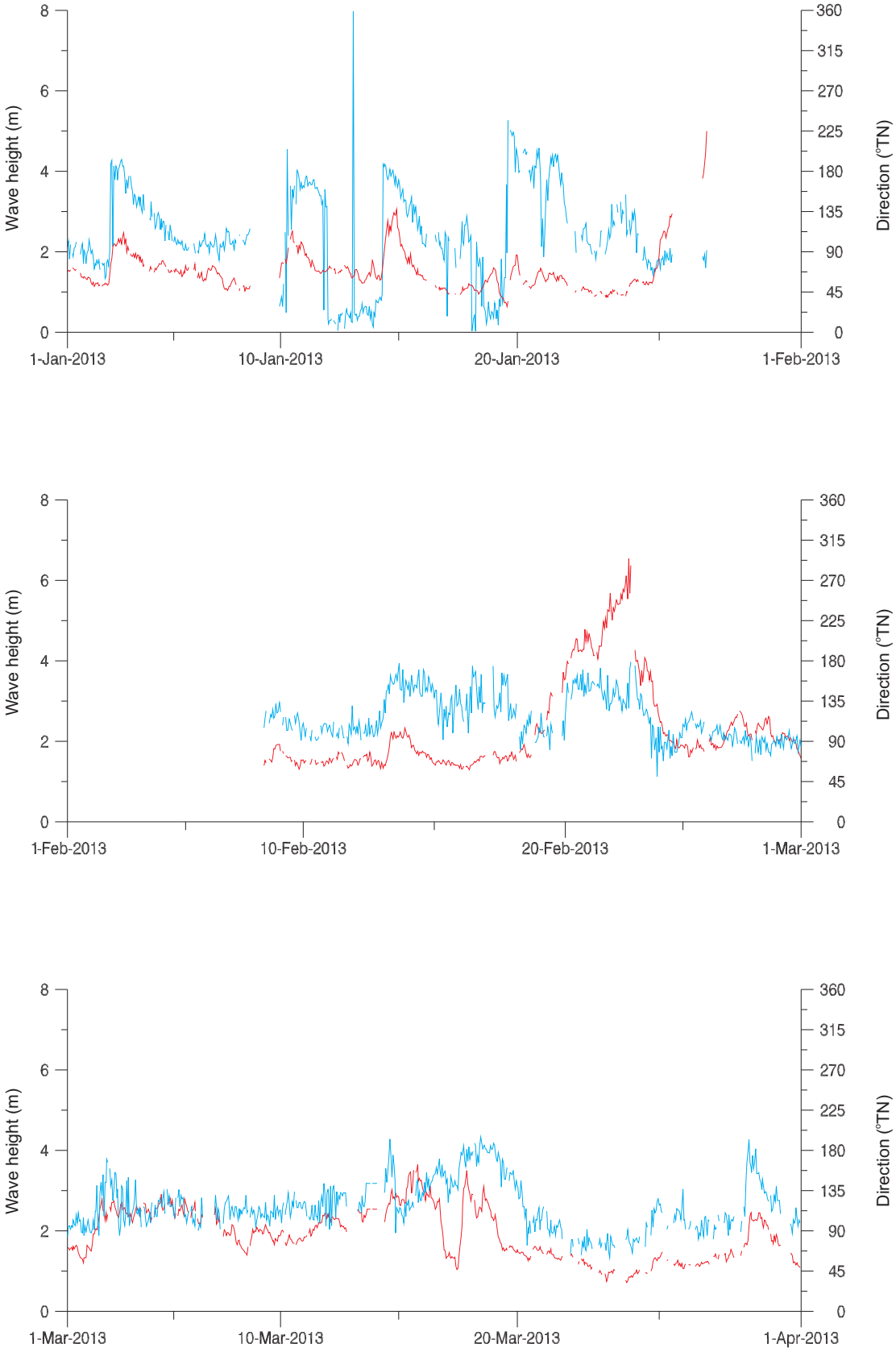
Table 2.2 Ocean Wave Storm Summary – 19 to 23 February 2013

Wave Conditions	Byron Bay	Coffs Harbour [1]	Crowdy Head
Peak Significant Wave Height (m)	6.5	6.9	6.4
Date and Time of Peak Significant Wave Height (hrs EST)	1000 22/02/2013	1500 22/02/2013	2100 22/02/2013
Peak Maximum Wave Height (m)	12.7	12.6	12.2
Spectral Peak wave period at storm peak (secs)	12.9	11.5	11.5
Wave Direction at Storm Peak (º TN)	127	150	132
Storm Duration for Hsig greater than 4 m (hrs)	59	38	37
Return Period for Storm Peak Hsig (yrs)	10	14	4

[1] Data not recorded by Coffs Harbour Waverider station due to extended mains power failure from 1700 hours 22 February to 0700 hours on 23 February 2013

Table 2.3 Ocean Wave Storm Summary – 1 to 5 March 2013

Wave Conditions	Byron Bay	Coffs Harbour	Crowdy Head
Peak Significant Wave Height (m)	2.9	3.3	4.0
Date and Time of Peak Significant Wave Height (hrs EST)	2300 04/03/2013	1900 02/03/2013	1400 02/03/2013
Peak Maximum Wave Height (m)	5.9	6.7	7.8
Spectral Peak wave period at storm peak (secs)	8.5	10.8	10.3
Wave Direction at Storm Peak (º TN)	120	165	136
Storm Duration for Hsig greater than 4 m (hrs)	0	0	1
Return Period for Storm Peak Hsig (yrs)	Not Applicable	< 0.1	0.15



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BYRON BAY WAVERIDER BUOY
SIGNIFICANT WAVE HEIGHT AND WAVE DIRECTION
JANUARY-MARCH 2013

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Figure 2.1

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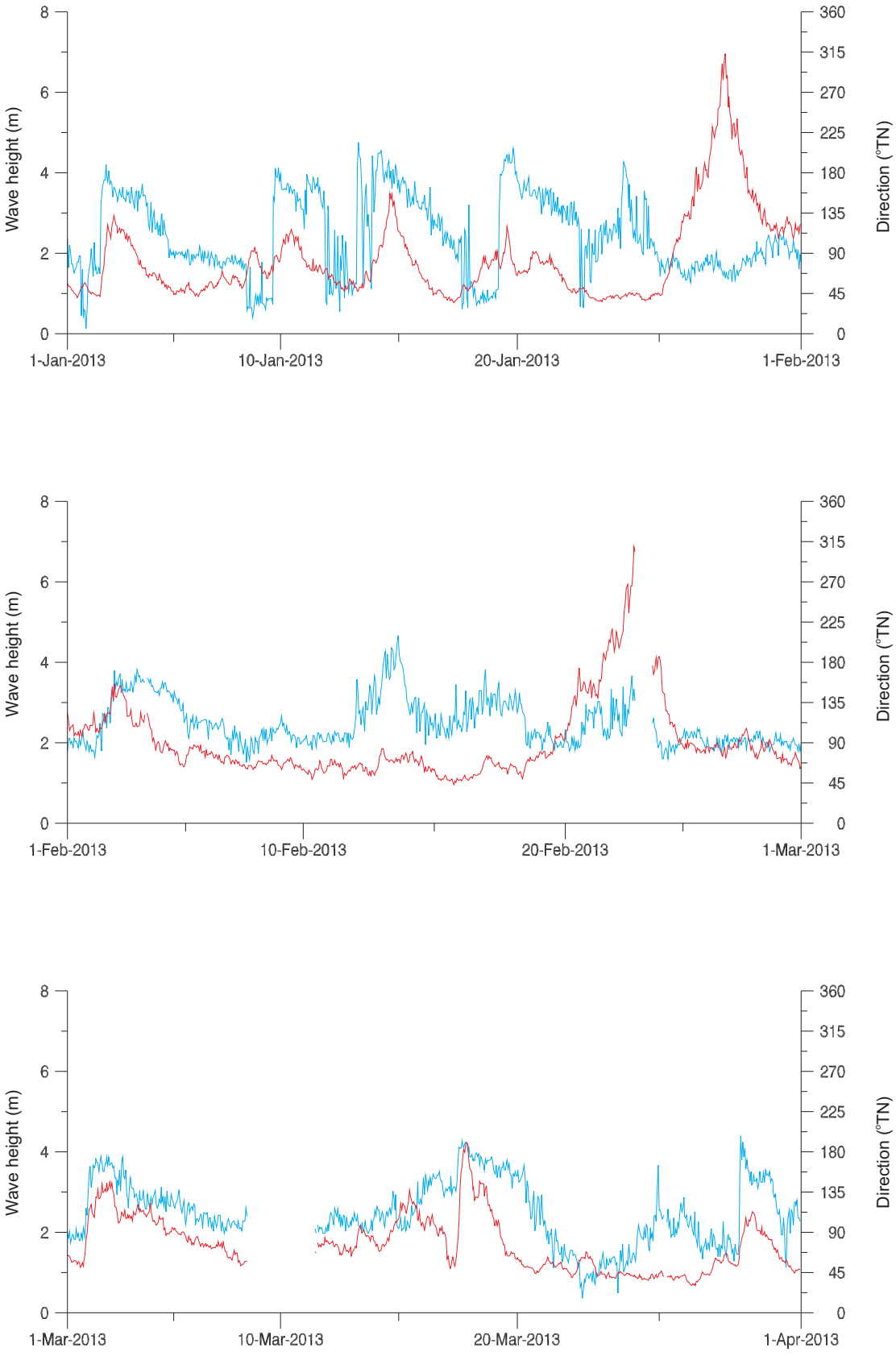

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COFFS HARBOUR WAVERIDER BUOY
SIGNIFICANT WAVE HEIGHT AND WAVE DIRECTION
JANUARY-MARCH 2013

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Figure 2.2

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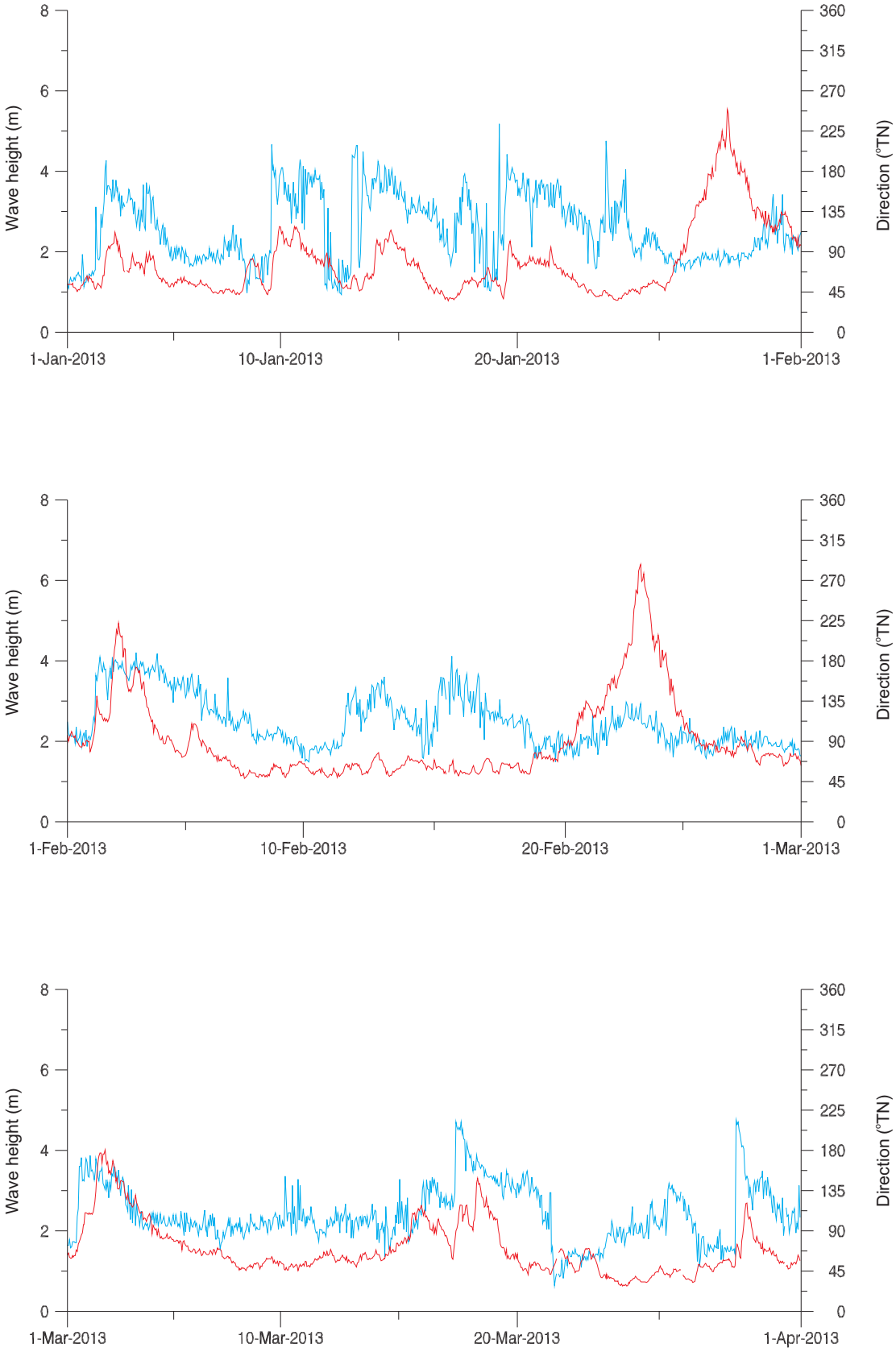

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CROWDY HEAD WAVERIDER BUOY
SIGNIFICANT WAVE HEIGHT AND WAVE DIRECTION
JANUARY-MARCH 2013

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Figure 2.3

DRAWING 2202-02-03.cdr

3. Tweed River Region

3.1 Tweed River Region Water Level

The locations of water level stations within the Tweed River region are shown in Figure 3.1. The water level data for the period 20 January to 20 March 2013 can be viewed graphically in Figures 3.2 and 3.3. The peak water levels are listed in Table 3.1.

Table 3.2 lists the Bureau of Meteorology flood classification for Murwillumbah. The BoM classification scheme indicates the flood peaks for Murwillumbah were classified as a moderate flood during the January event and minor floods during February and March.

Table 3.1 Tweed River Region Flood Peaks

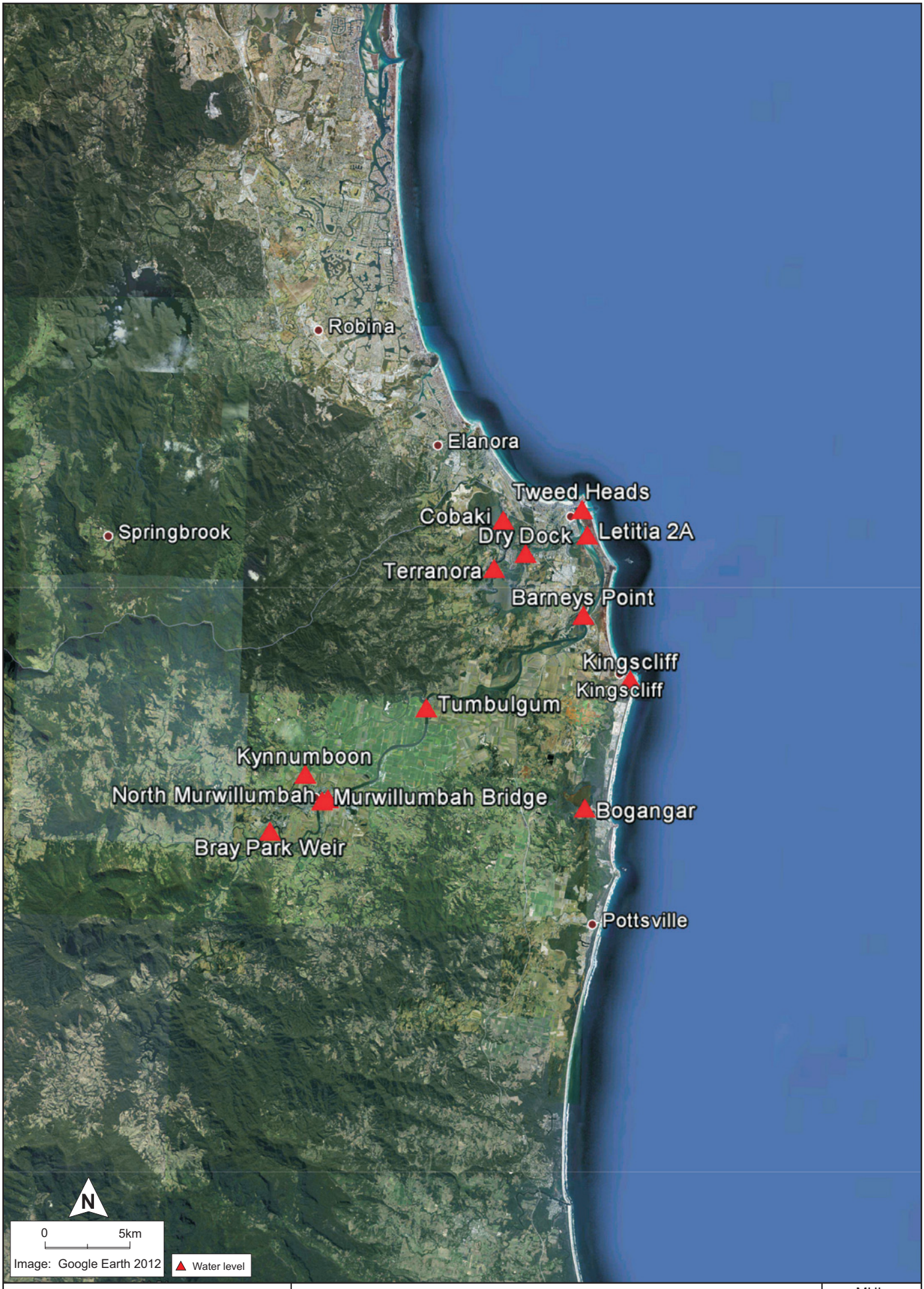
Station	Datum	Peak level (m)	Event 1 Time/Date	Peak level (m)	Event 2 Time/Date	Peak level (m)	Event 3 Time/Date
Tweed Heads	TRHD	2.27	0915 28/01/2013	1.87	0630 23/02/2013	-	-
Cobaki	TRHD	2.12	1100 28/01/2013	1.72	0815 22/02/2013	-	-
Letitia 2A	TRHD	2.25	0930 28/01/2013	1.88	0730 23/02/2013	-	-
Dry Dock	TRHD	2.16	1030 28/01/2013	1.78	0715 22/02/2013	-	-
Terranora	TRHD	2.22	1045 28/01/2013	1.80	0800 22/02/2013	-	-
Barneys Point	TRHD	2.66	1000 29/01/2013	1.90	0730 23/02/2013	1.72	0045 03/03/2013
Tumbulgum	TRHD	4.08	0030 29/01/2013	2.07	0815 23/02/2013	2.19	0215 03/03/2013
Kynnumboon	TRHD	5.40	1515 28/01/13	3.24	0730 19/02/2013	3.27	0245 03/03/2013
North Murwillumbah	TRHD	5.69	1700 28/01/2013	2.32	2130 22/02/2013	2.59	0230 03/03/2013
Murwillumbah Bridge	TRHD	5.53	1645 28/01/2013	2.26	2200 22/02/2013	2.55	0230 03/03/2013
Bray Park Weir	TRHD	7.51	1545 28/01/2013	3.75	2030 22/02/2013	3.76	2045 02/03/2013
Bogangar	BFMD	1.88	2130 29/01/2013	1.80	0915 22/02/2013	1.98	0045 04/03/2013

- No discernible flood hydrograph recorded at these stations
TRHD Tweed River Hydro Datum, BFMD Brunswick River Flood Mitigation Datum

Table 3.2 BoM Flood Gauge Classification for Tweed River Region

Station	Classification			Peak (m)	Classification
	Minor	Moderate	Major		
	Water Level TRHD (m)				
North Murwillumbah*	3.9 (3.0 m AHD)	4.9 (4.0 m AHD)	5.7 (4.8 m AHD)	5.69 (28/01/2013)	Moderate
				2.32 (22/02/2013)	Minor
				2.59 (03/03/2013)	Minor

*BoM flood classification levels have been converted from AHD (Australian Height Datum) to TRHD (Tweed River Hydro Datum)



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STATION LOCATIONS
TWEED RIVER REGION

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Figure 3.1

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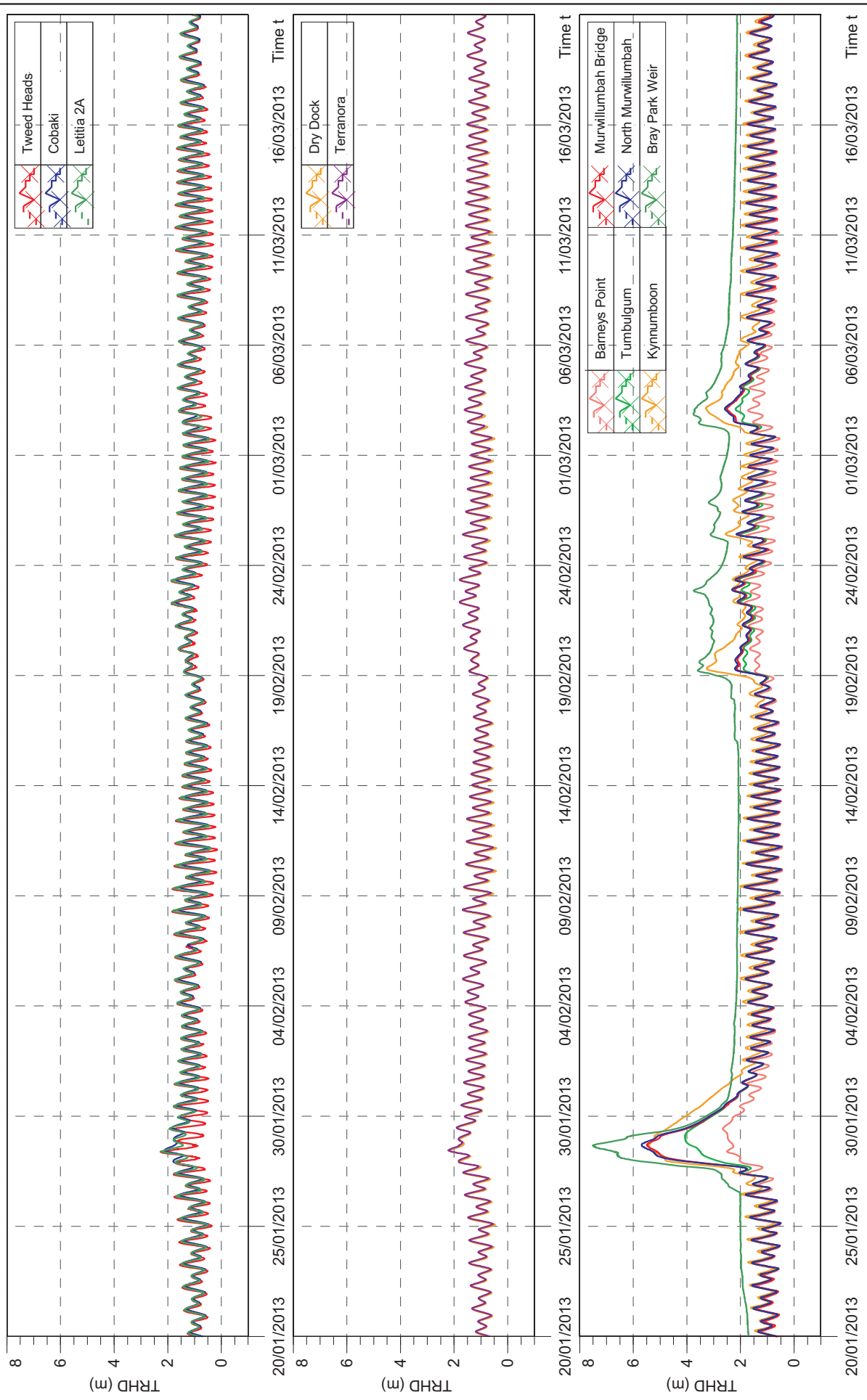

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TWEED RIVER REGION
WATER LEVEL DATA
20 JANUARY-20 MARCH 2013

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Figure 3.2

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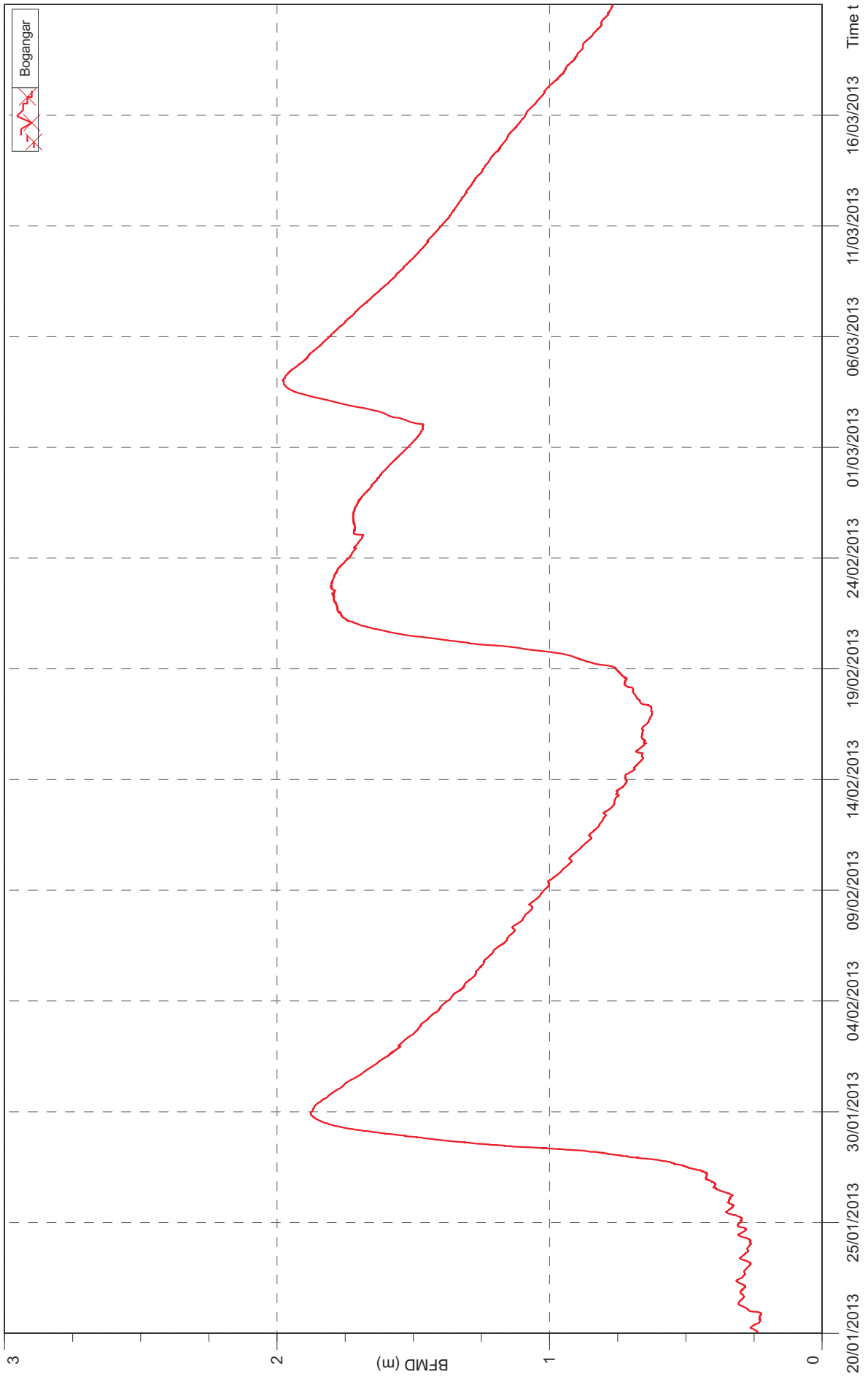

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TWEED RIVER REGION
WATER LEVEL DATA
20 JANUARY-20 MARCH 2013

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Figure 3.3

DRAWING 2202-03-03.cdr

4. Brunswick River Region

4.1 Brunswick River Region Water Level

The locations of water level stations within the Brunswick River region are shown in Figure 4.1. The water level data for the period 20 January to 20 March 2013 can be viewed graphically in Figure 4.2. The peak water levels are listed in Table 4.1.

Table 4.2 lists the Bureau of Meteorology flood classification for Billinudgel and Mullumbimby. The BoM classification scheme indicates the flood peaks for Billinudgel were below minor for all three events. The flood peaks for Mullumbimby were classified as minor during the January flood and below minor for the February and March floods.

Table 4.1 Brunswick River Region Flood Peaks

Station	Datum	Peak level (m)	Event 1 Time/Date	Peak level (m)	Event 2 Time/Date	Peak level (m)	Event 3 Time/Date
Billinudgel	BFMD	2.46	0300 28/01/2013	1.90	2045 22/02/2013	2.19	2130 02/03/2013
Orana Bridge	BFMD	1.52	0930 28/01/2013	1.22	0715 23/02/2013	1.07	0015 03/03/2013
Brunswick Heads	BFMD	1.38	0930 28/01/2013	1.06	0615 23/02/2013	-	-
Mullumbimby	BFMD	3.22	0245 28/01/2013	1.70	2000 22/02/2013	1.70	1345 02/03/2013

- No discernible flood hydrograph recorded at this station
BFMD Brunswick River Flood Mitigation Datum

Table 4.2 BoM Flood Gauge Classification for Brunswick River Region

Station	Classification			Peak (m)	Classification
	Minor	Moderate	Major		
	Water Level BFMD (m)				
Billinudgel	2.5	3	3.5	2.463 (28/01/2013)	Below Minor
				1.900 (22/02/2013)	Below Minor
				2.186 (02/03/2013)	Below Minor
Mullumbimby	2.5	3.5	4.5	3.218 (28/01/2013)	Minor
				1.703 (22/02/2013)	Below Minor
				1.698 (02/03/2013)	Below Minor

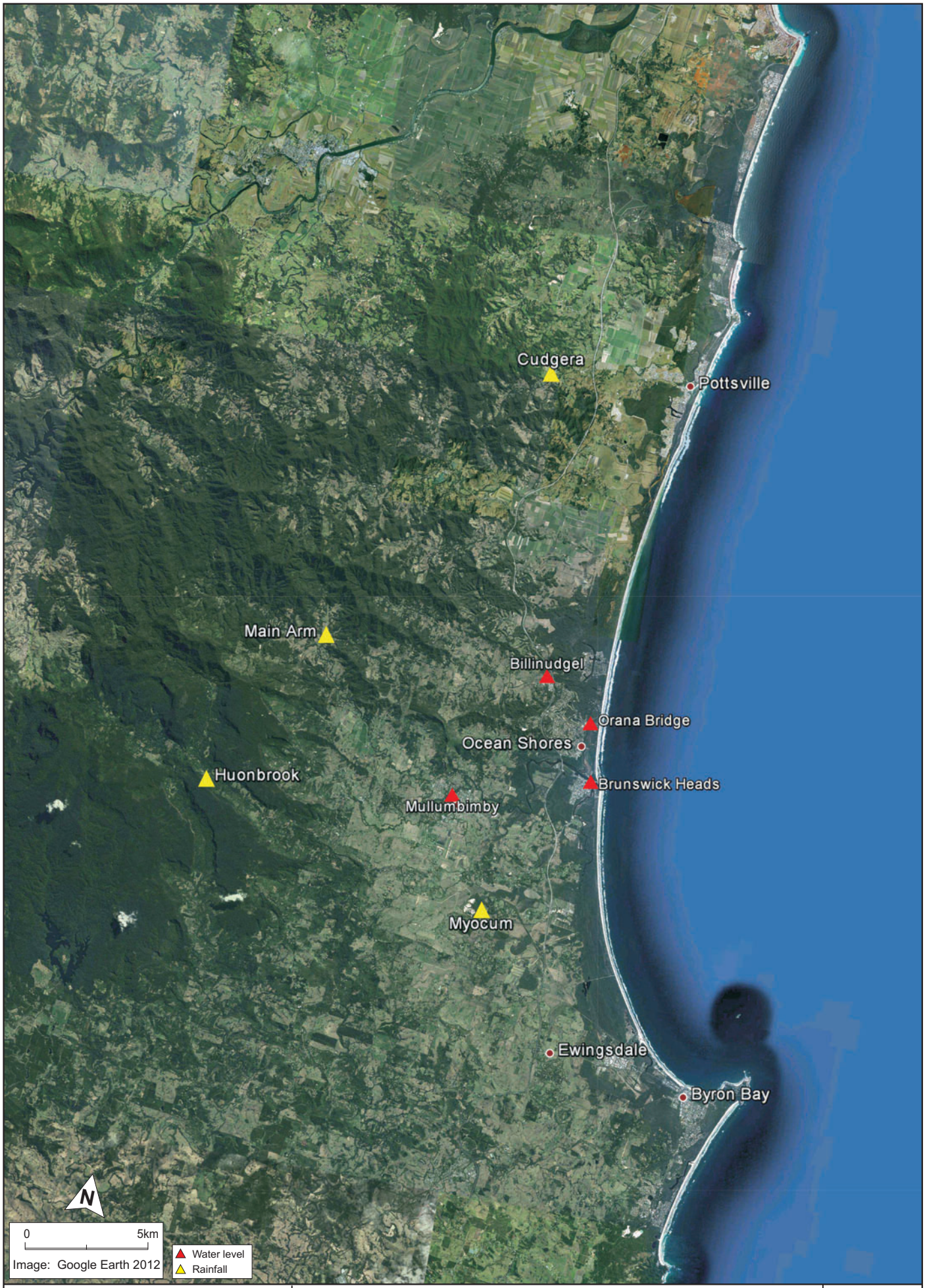
BFMD Brunswick River Flood Mitigation Datum

4.2 Brunswick River Region Rainfall

9.00 a.m. daily rainfall totals are displayed in Figure 4.3 and Table 4.3 for the period 24 January to 5 March 2013. The rainfall data and intensities are displayed graphically in Figures 4.4 to 4.7.

Table 4.3 Brunswick River Region Daily Rainfall Totals

Date	Cudgera (mm)	Main Arm (mm)	Myocum (mm)	Huonbrook (mm)
24/01/2013	3.0	1.5	1.0	5.5
25/01/2013	40.5	10.0	12.5	11.0
26/01/2013	13.5	37.0	5.5	80.0
27/01/2013	53.5	64.0	34.0	112.0
28/01/2013	176.5	308.0	155.5	454.5
29/01/2013	52.5	138.0	15.5	228.0
30/01/2013	0.0	0.0	0.0	0.0
31/01/2013	0.0	2.0	2.0	1.0
01/02/2013	0.0	0.0	0.0	0.5
02/02/2013	16.0	4.0	3.0	1.5
03/02/2013	0.0	1.0	11.0	2.5
04/02/2013	0.0	0.0	0.0	0.0
05/02/2013	3.5	0.0	0.0	1.0
06/02/2013	14.0	24.5	19.0	14.5
07/02/2013	3.0	7.5	16.0	17.0
08/02/2013	2.0	3.5	10.0	6.5
09/02/2013	1.5	8.5	24.0	5.0
10/02/2013	0.0	1.0	0.5	1.5
11/02/2013	0.0	0.0	0.0	0.0
12/02/2013	0.0	1.5	1.0	2.0
13/02/2013	13.0	8.5	7.5	10.0
14/02/2013	0.0	0.0	0.0	0.5
15/02/2013	5.5	18.5	24.0	10.5
16/02/2013	31.0	51.0	45.0	51.5
17/02/2013	9.5	31.5	9.5	12.0
18/02/2013	10.5	37.5	22.5	13.5
19/02/2013	57.0	70.5	68.0	94.5
20/02/2013	69.5	57.0	53.5	60.0
21/02/2013	34.0	28.5	39.5	64.5
22/02/2013	34.5	32.5	49.0	68.5
23/02/2013	19.5	39.5	80.0	73.0
24/02/2013	14.5	4.5	7.5	0.5
25/02/2013	29.5	39.5	41.0	49.0
26/02/2013	3.5	11.0	8.0	36.0
27/02/2013	10.5	9.0	9.5	24.5
28/02/2013	8.5	19.5	13.0	28.5
01/03/2013	0.0	0.5	0.0	0.0
02/03/2013	95.0	84.0	76.5	81.5
03/03/2013	58.0	66.0	72.5	86.0
04/03/2013	12.5	27.5	15.5	33.5
05/03/2013	21.5	19.5	9.5	25.0
Total	**917.0**	**1268.0**	**962.0**	**1767.0**



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STATION LOCATIONS
BRUNSWICK RIVER REGION

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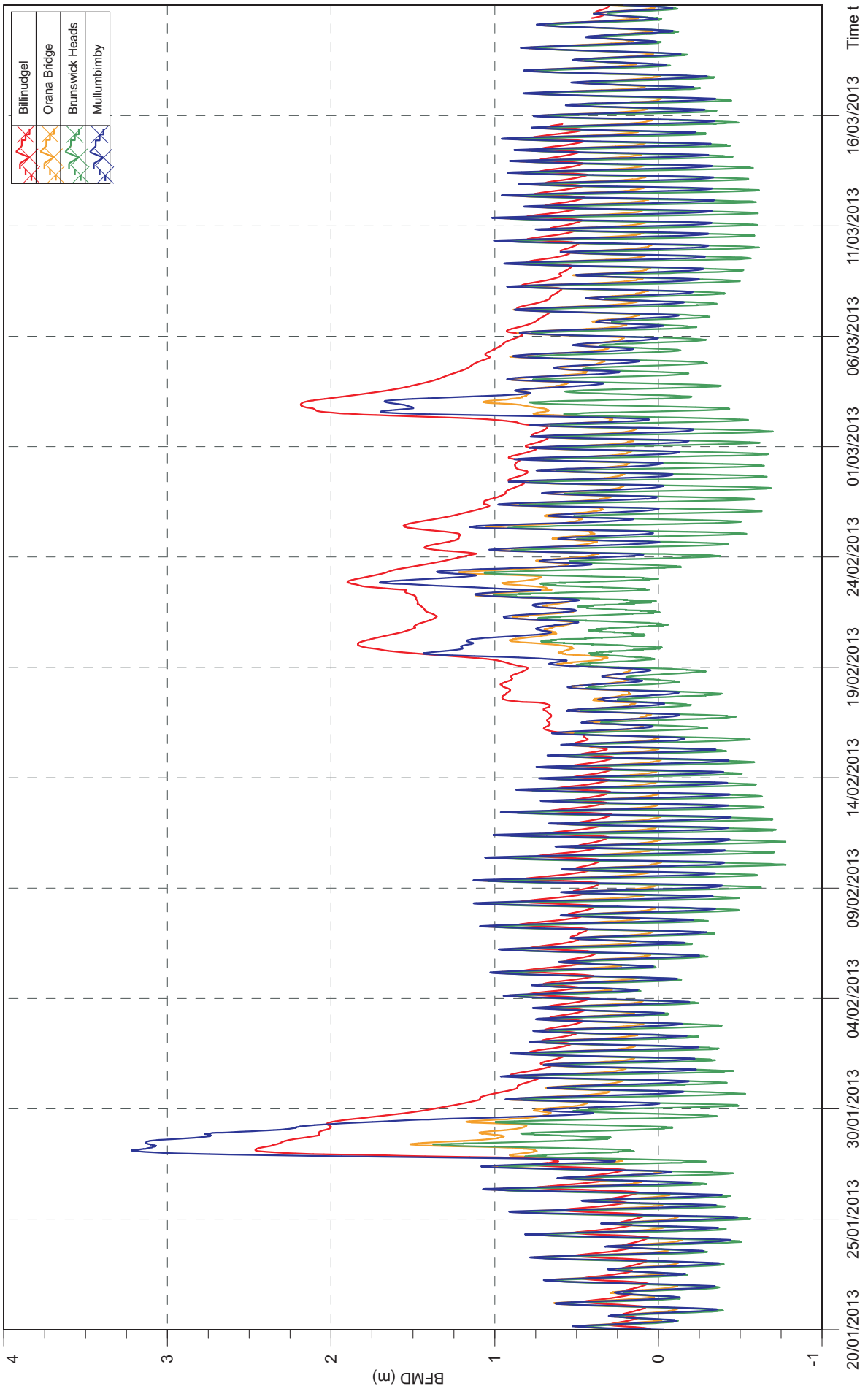
Figure 4.1

DRAWING 2202-04-01.cdr



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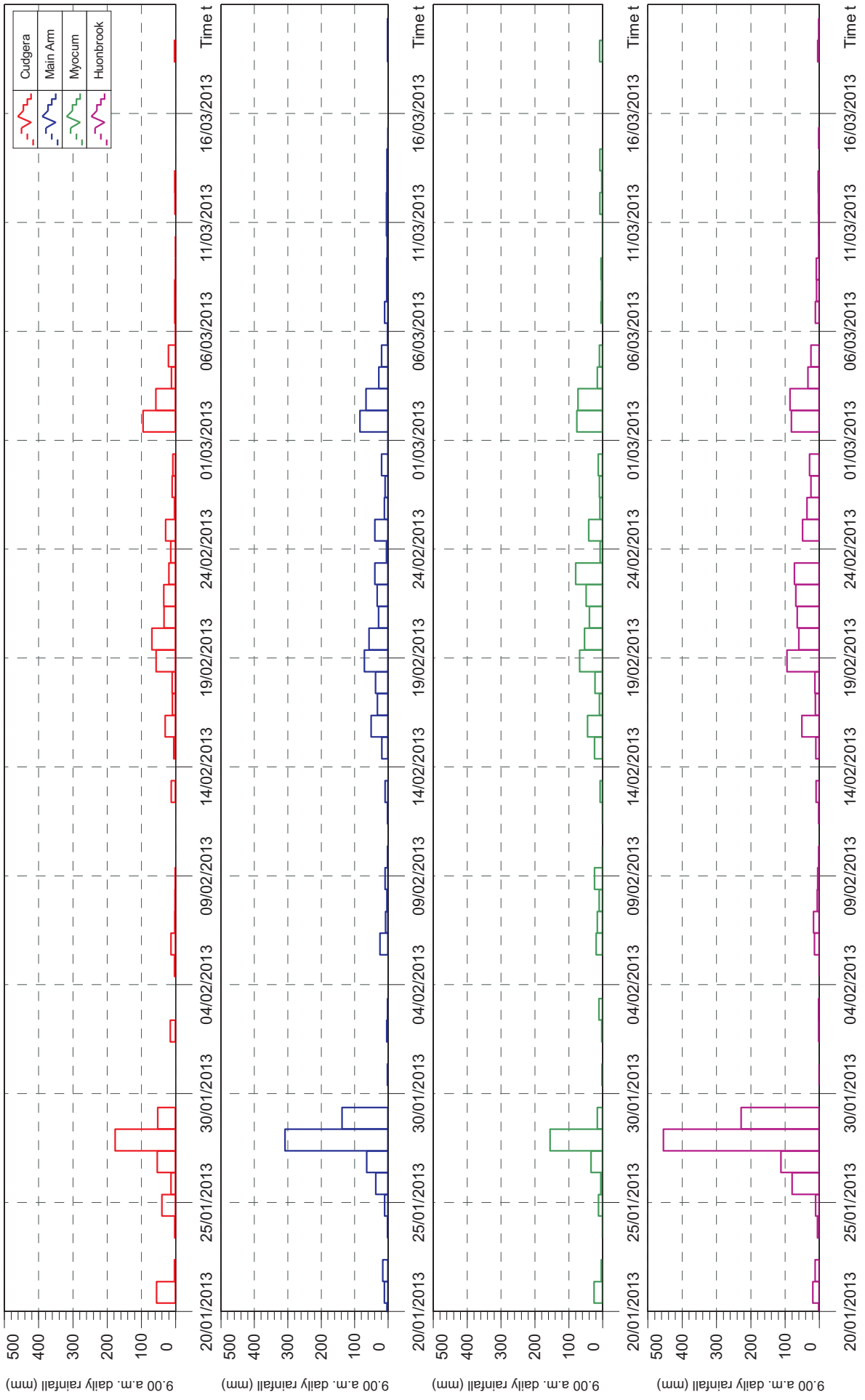
BRUNSWICK RIVER REGION
WATER LEVEL DATA
20 JANUARY-20 MARCH 2013

MHL Report 2202

Figure 4.2

DRAWING 2202-04-02.cdr



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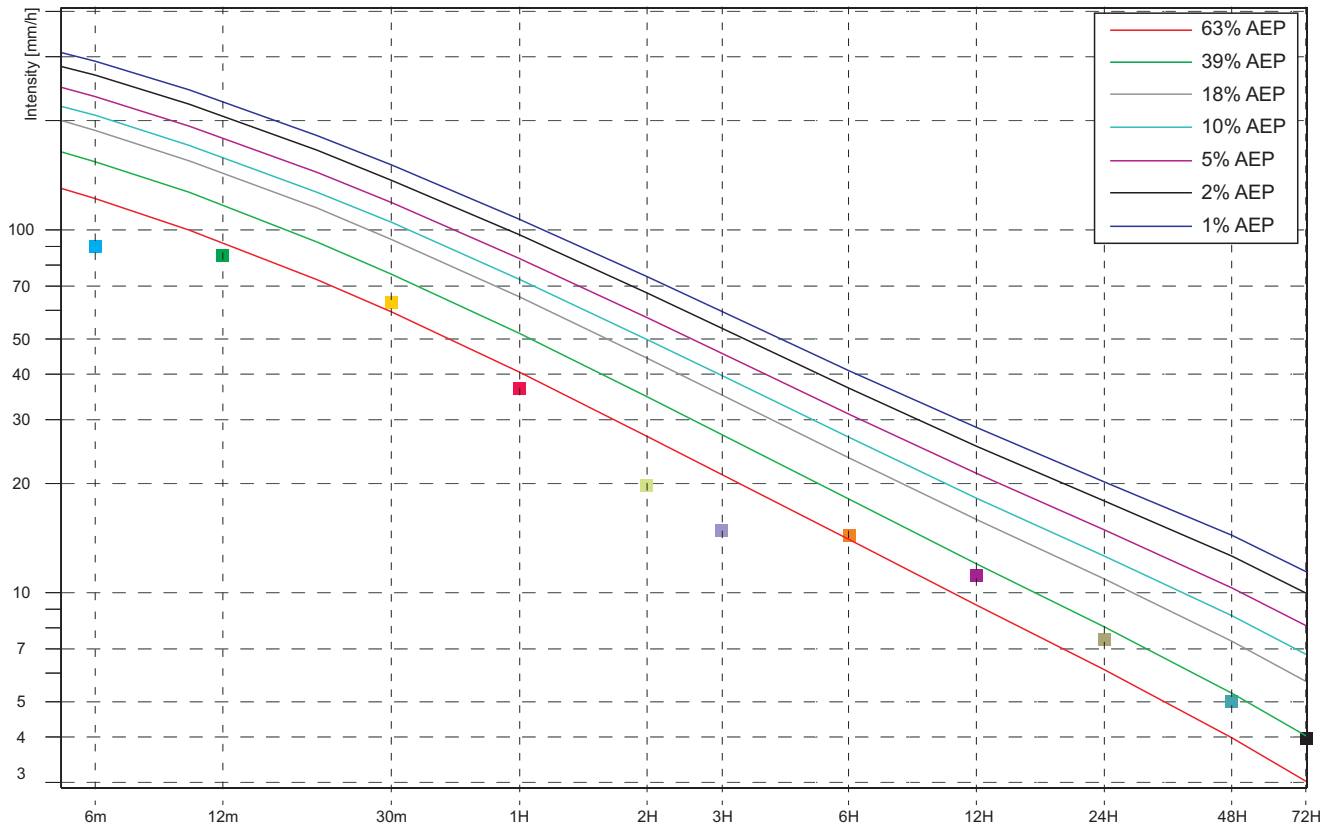
BRUNSWICK RIVER REGION
RAINFALL DATA
20 JANUARY-20 MARCH 2013

MHL Report 2202

Figure 4.3

DRAWING 2202-04-03.cdr



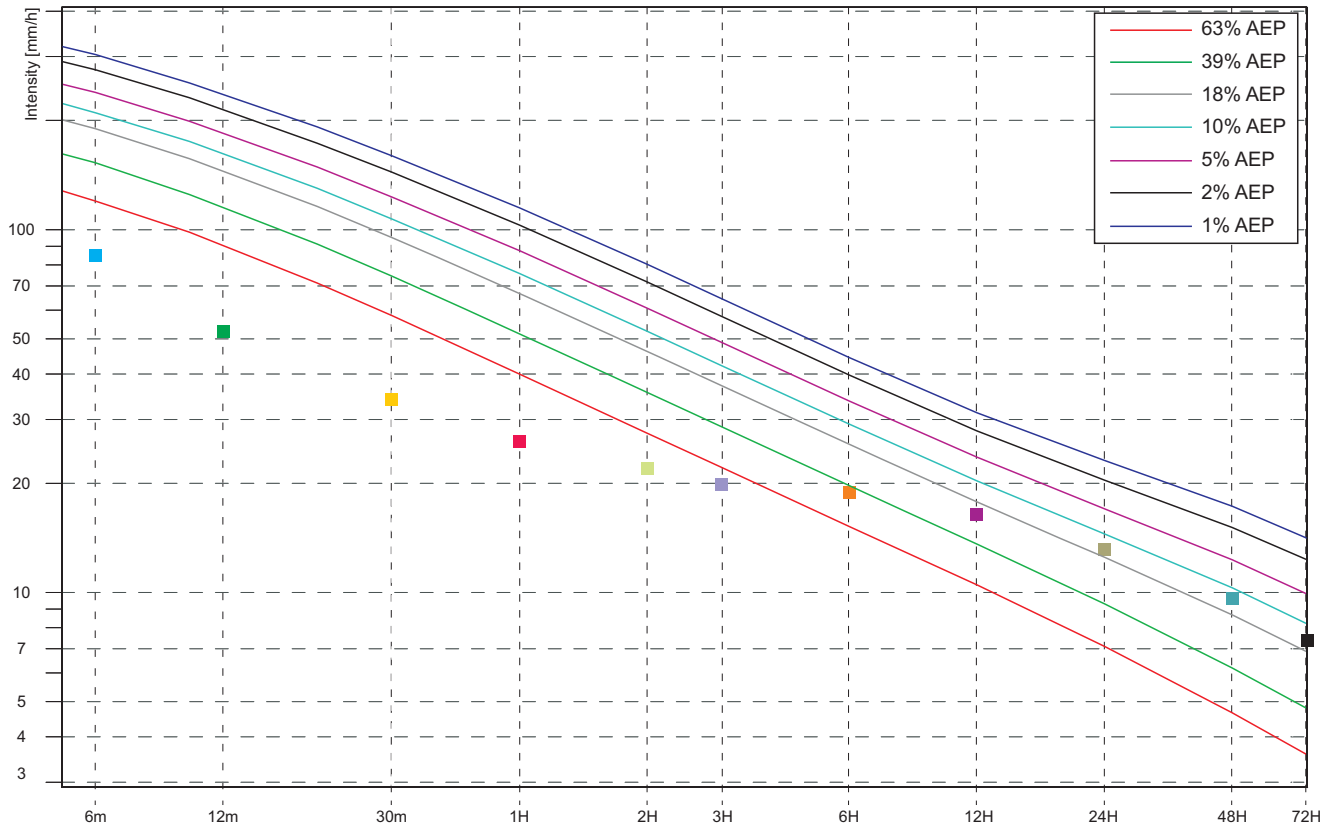
Duration
(minutes: m, hours: H)
Reference: Australian Rainfall and Runoff 1987

Cudgera Rainfall Intensity 21 January-21 March 2013		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	90.00	21/01/2013 0:40
12m	85.00	21/01/2013 0:40
30m	63.00	21/01/2013 0:50
1H	36.50	21/01/2013 1:16
2H	19.75	21/01/2013 1:38
3H	14.84	27/01/2013 17:22
6H	14.34	27/01/2013 20:20
12H	11.13	28/01/2013 0:46
24H	7.41	28/01/2013 8:10
48H	5.02	29/01/2013 3:16
72H	3.96	29/01/2013 3:22

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:
Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

The use of the term 'Average Recurrence Interval' (ARI) can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of Annual Exceedance Probability (AEP). For example, 'a rainfall total of 60mm falling in 3 hours at Cudgera has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year' can be easier to understand than the equivalent statement of 'rainfall total of 60mm in 3 hours has an ARI of 100 years'.

Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml



Duration
(minutes: m, hours: H)
Reference: Australian Rainfall and Runoff 1987

Main Arm Rainfall Intensity 21 January-21 March 2013		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	85.00	24/02/2013 16:32
12m	52.50	15/02/2013 16:42
30m	34.00	28/01/2013 16:14
1H	26.00	28/01/2013 16:30
2H	22.00	27/01/2013 16:28
3H	19.84	27/01/2013 16:48
6H	18.92	27/01/2013 19:42
12H	16.38	28/01/2013 1:20
24H	13.15	28/01/2013 11:32
48H	9.62	29/01/2013 2:58
72H	7.36	29/01/2013 3:08

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:
Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

The use of the term 'Average Recurrence Interval' (ARI) can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of Annual Exceedance Probability (AEP). For example, 'a rainfall total of 60mm falling in 3 hours at Cudgera has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year' can be easier to understand than the equivalent statement of 'rainfall total of 60mm in 3 hours has an ARI of 100 years'.

Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml

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MAIN ARM INTENSITY-FREQUENCY-DURATION
21 JANUARY-21 MARCH 2013

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Figure 4.5
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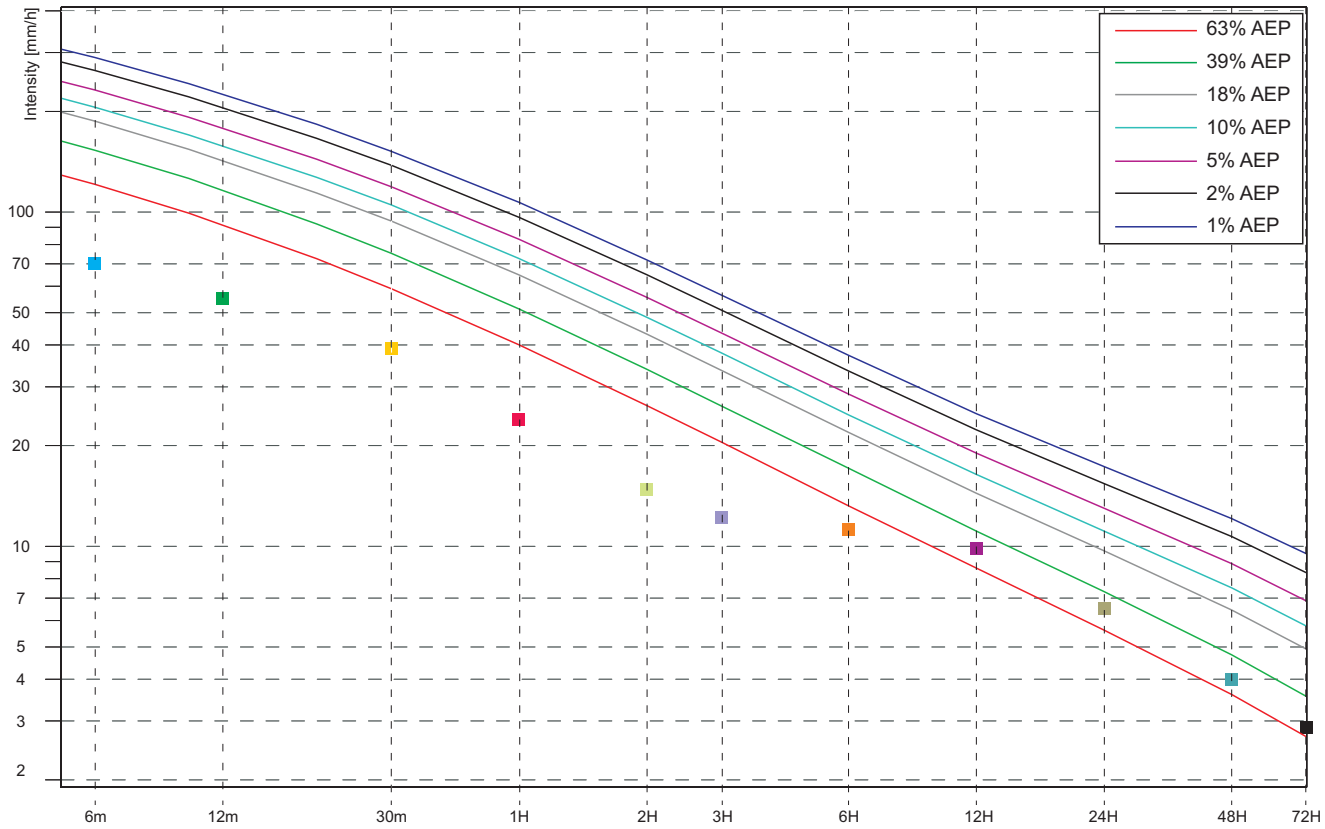

Duration
(minutes: m, hours: H)
Reference: Australian Rainfall and Runoff 1987

Myocum Rainfall Intensity 21 January-21 March 2013		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	70.00	18/02/2013 17:04
12m	55.00	18/02/2013 17:02
30m	39.00	18/02/2013 17:16
1H	24.00	22/02/2013 19:38
2H	14.75	22/02/2013 20:34
3H	12.17	27/01/2013 19:58
6H	11.25	27/01/2013 19:52
12H	9.84	28/01/2013 0:52
24H	6.50	28/01/2013 8:38
48H	3.98	28/01/2013 10:46
72H	2.87	29/01/2013 3:40

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:
Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

The use of the term 'Average Recurrence Interval' (ARI) can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of Annual Exceedance Probability (AEP). For example, 'a rainfall total of 60mm falling in 3 hours at Cudgera has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year' can be easier to understand than the equivalent statement of 'rainfall total of 60mm in 3 hours has an ARI of 100 years'.

Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml

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MYOCUM INTENSITY-FREQUENCY-DURATION
21 JANUARY-21 MARCH 2013

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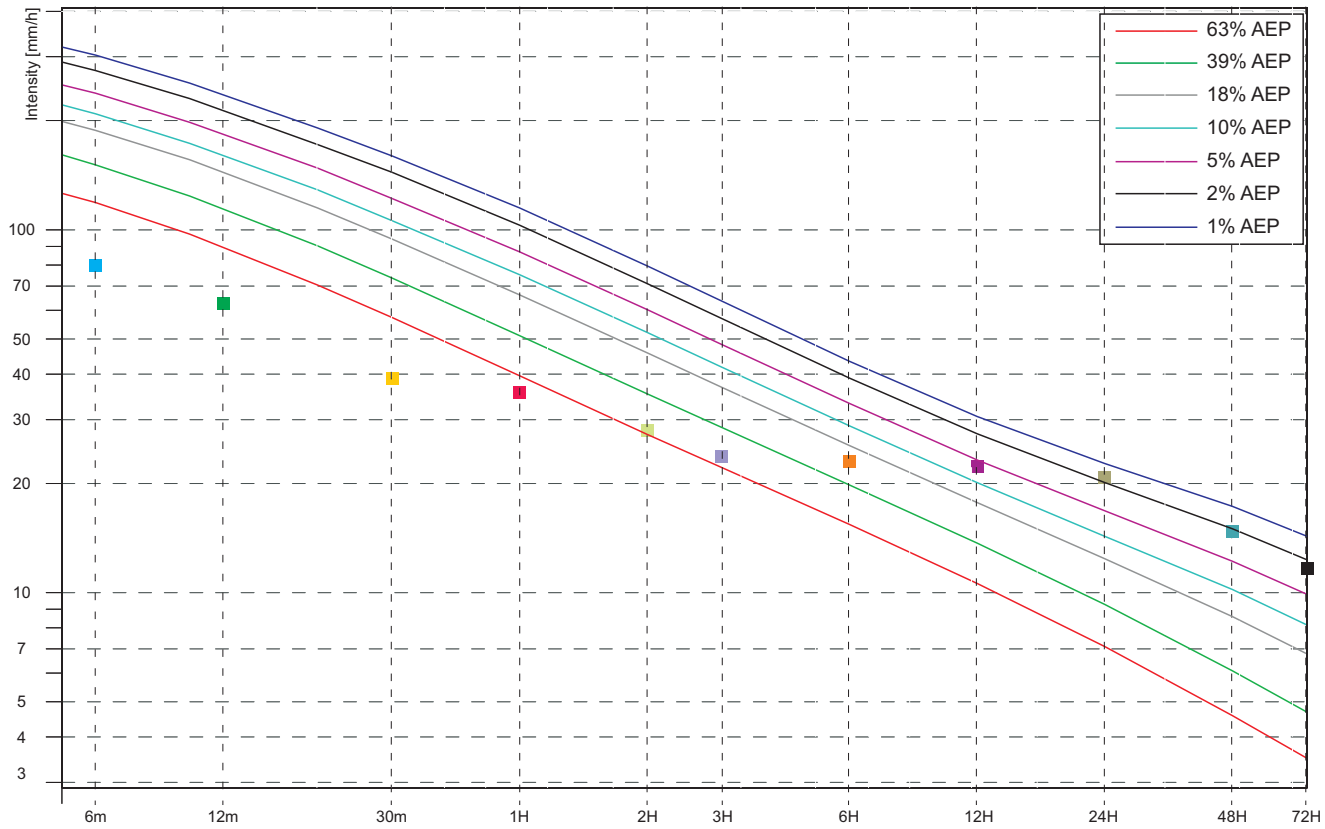
Figure 4.6
DRAWING 2202-04-06.cdr



Duration
(minutes: m, hours: H)
Reference: Australian Rainfall and Runoff 1987

Huonbrook Rainfall Intensity 21 January-21 March 2013		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	80.00	18/02/2013 17:24
12m	62.50	18/02/2013 17:28
30m	39.00	26/01/2013 14:56
1H	35.50	28/01/2013 9:16
2H	28.00	28/01/2013 9:34
3H	23.67	27/01/2013 20:34
6H	22.92	28/01/2013 3:36
12H	22.25	28/01/2013 9:34
24H	20.73	28/01/2013 12:44
48H	14.75	29/01/2013 2:28
72H	11.67	29/01/2013 0:44

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:
Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

The use of the term 'Average Recurrence Interval' (ARI) can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of Annual Exceedance Probability (AEP). For example, 'a rainfall total of 60mm falling in 3 hours at Cudgera has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year' can be easier to understand than the equivalent statement of 'rainfall total of 60mm in 3 hours has an ARI of 100 years'.

Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml

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Manly Hydraulics Laboratory

HUONBROOK INTENSITY-FREQUENCY-DURATION
21 JANUARY-21 MARCH 2013

MHL Report 2202
Figure 4.7
DRAWING 2202-04-07.cdr

5. Richmond River Region

5.1 Richmond River Region Water Level

The locations of water level stations within the Richmond River region are shown in Figure 5.1. The water level data for the period 20 January to 20 March 2013 can be viewed graphically in Figures 5.2, 5.3 and 5.4. The peak water levels are listed in Table 5.1.

Table 5.2 lists the Bureau of Meteorology flood classification for Coraki, Bungawalbin and Woodburn. The BoM classification scheme indicates the flood peaks for Bungawalbin were classified as major for the January flood and moderate for the February and March events.

Table 5.1 Richmond River Region Flood Peaks

Station	Datum	Peak level (m)	Event 1 Time/Date	Peak level (m)	Event 2 Time/Date	Peak level (m)	Event 3 Time/Date
Lake Ainsworth	AHD	^	^	^	^	2.46	8/3/2013
Woodlawn	RRVD	10.80	0645 29/01/2013	9.46	2100 23/02/2013	7.38	2000 03/03/2013
Tuncester	RRVD	10.95	0745 29/01/2013	10.30	1400 23/02/2013	6.91	1715 03/03/2013
Lismore Rowing Club^^	RRVD	10.29	0929 29/01/2013	8.980	1733 23/02/2013	6.42	1825 03/03/2013
East Gundurimba	RRVD	9.59	1300 29/01/2013	8.46	2045 23/02/2013	6.15	2015 03/03/2013
Missingham Bridge	RRVD	1.94	1115 31/01/2013	2.17	0700 23/02/2013	-	-
Byrnes Point	RRVD	1.85	1130 31/01/2013	2.04	0645 22/02/2013	-	-
Ballina Breakwall	RRVD	-	-	2.01	0630 22/02/2013	-	-
Wardell	RRVD	2.04	1115 30/01/2013	2.13	0715 22/02/2013	1.91	0315 05/03/2013
Bungawalbin	RRVD	5.01	1130 30/01/2013	5.00	1400 24/02/2013	4.00	1045 04/03/2013
Woodburn	RRVD	3.70	1400 30/01/2013	3.66	1130 24/02/2013	2.90	1600 04/03/2013
Tucombil Highway Bridge	RRVD	3.07	1415 30/01/2013	#	#	2.58	0615 04/03/2013
Tucombil Floodgate	RRVD	2.57	1530 30/01/2013	2.63	2345 24/02/2013	2.14	0500 05/03/2013
Rocky Mouth Creek*	RRVD	1.93	2115 01/02/2013	2.74	1245 26/02/2013	2.51	0630 05/03/2013
Coraki	RRVD	#	#	5.54	1100 24/02/2013	4.34	0945 04/03/2013

Station	Datum	Peak level (m)	Event 1 Time/Date	Peak level (m)	Event 2 Time/Date	Peak level (m)	Event 3 Time/Date
Evans River Fishing Co-op	RRVD	2.15	0915 28/01/2013	1.91	0615 22/02/2013	1.75	0715 10/03/2013
Iron Gates	RRVD	2.10	0945 28/01/2013	1.87	0645 23/02/2013	-	-

AHD Australian Height Datum, RRVD Richmond River Valley Datum ^ Lake system peaked at 2.463 m AHD on 8/3/13
^^ Lismore City Council station - No discernible flood hydrograph recorded at these stations * Influenced by floodgates
# The automatic water level recorder (AWLR) at Coraki failed to capture the January flood peak and Tucombil Highway Bridge failed to capture the February flood peak (refer to Appendix A – Station Performance).

Table 5.2 BoM Flood Gauge Classification for Richmond River Region

Station	Classification			Peak (m)	Classification
	Minor	Moderate	Major		
	Water Level RRVD (m)				
Coraki	3.4	5.0	5.7	#	#
				5.54 (24/02/2013)	Moderate
				4.34 (04/03/2013)	Minor
Bungawalbin	3.0	4.5	5.0	5.01 (30/01/2013)	Major
				5.00 (24/02/2013)	Moderate
				4.00 (04/03/2013)	Moderate
Woodburn	3.2	3.7	4.2	3.70 (30/01/2013)	Moderate
				3.65 (24/02/2013)	Minor
				2.90 (04/03/2013)	Below Minor

The AWLR at Coraki failed to capture the January flood peak (refer to Appendix A Station Performance)
RRVD Richmond River Valley Datum

5.2 Richmond River Region Rainfall

9.00 a.m. daily rainfall totals are displayed in Figure 5.4 and Table 5.3 for the periods 24 January to 5 March 2013. The rainfall data and intensities are displayed graphically in Figure 5.5.

Table 5.3 Richmond River Region Daily Rainfall Totals

Date	Lake Ainsworth (mm)
24/01/2013	0.5
25/01/2013	22.5
26/01/2013	5.0
27/01/2013	55.0
28/01/2013	145.5
29/01/2013	40.5
30/01/2013	1.0

Date	Lake Ainsworth (mm)
31/01/2013	0.5
01/02/2013	0.0
02/02/2013	6.5
03/02/2013	0.0
04/02/2013	0.0
05/02/2013	0.0
06/02/2013	28.0
07/02/2013	7.5
08/02/2013	*
09/02/2013	*
10/02/2013	*
11/02/2013	*
12/02/2013	*
13/02/2013	*
14/02/2013	*
15/02/2013	*
16/02/2013	*
17/02/2013	*
18/02/2013	*
19/02/2013	*
20/02/2013	22.5
21/02/2013	30.0
22/02/2013	29.0
23/02/2013	70.0
24/02/2013	0.0
25/02/2013	48.0
26/02/2013	0.0
27/02/2013	20.0
28/02/2013	0.0
01/03/2013	0.0
02/03/2013	35.5
03/03/2013	59.5
04/03/2013	9.5
05/03/2013	9.5
Total	**648.5**

*Rain catch blocked 8-19 February 2013

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STATION LOCATIONS
RICHMOND RIVER REGION

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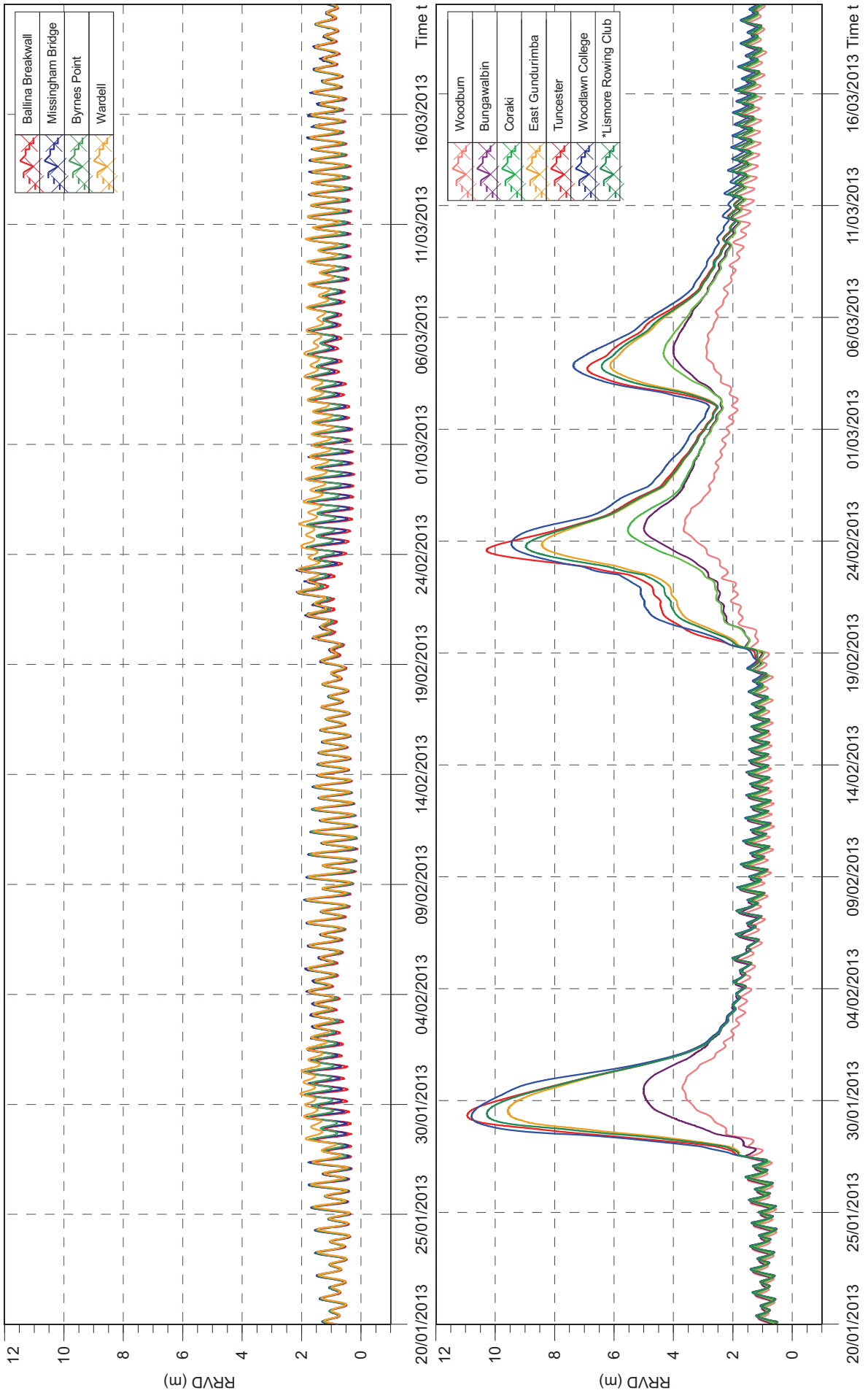
Figure 5.1

DRAWING 2202-05-01.cdr



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RICHMOND RIVER REGION
WATER LEVEL DATA
20 JANUARY-20 MARCH 2013

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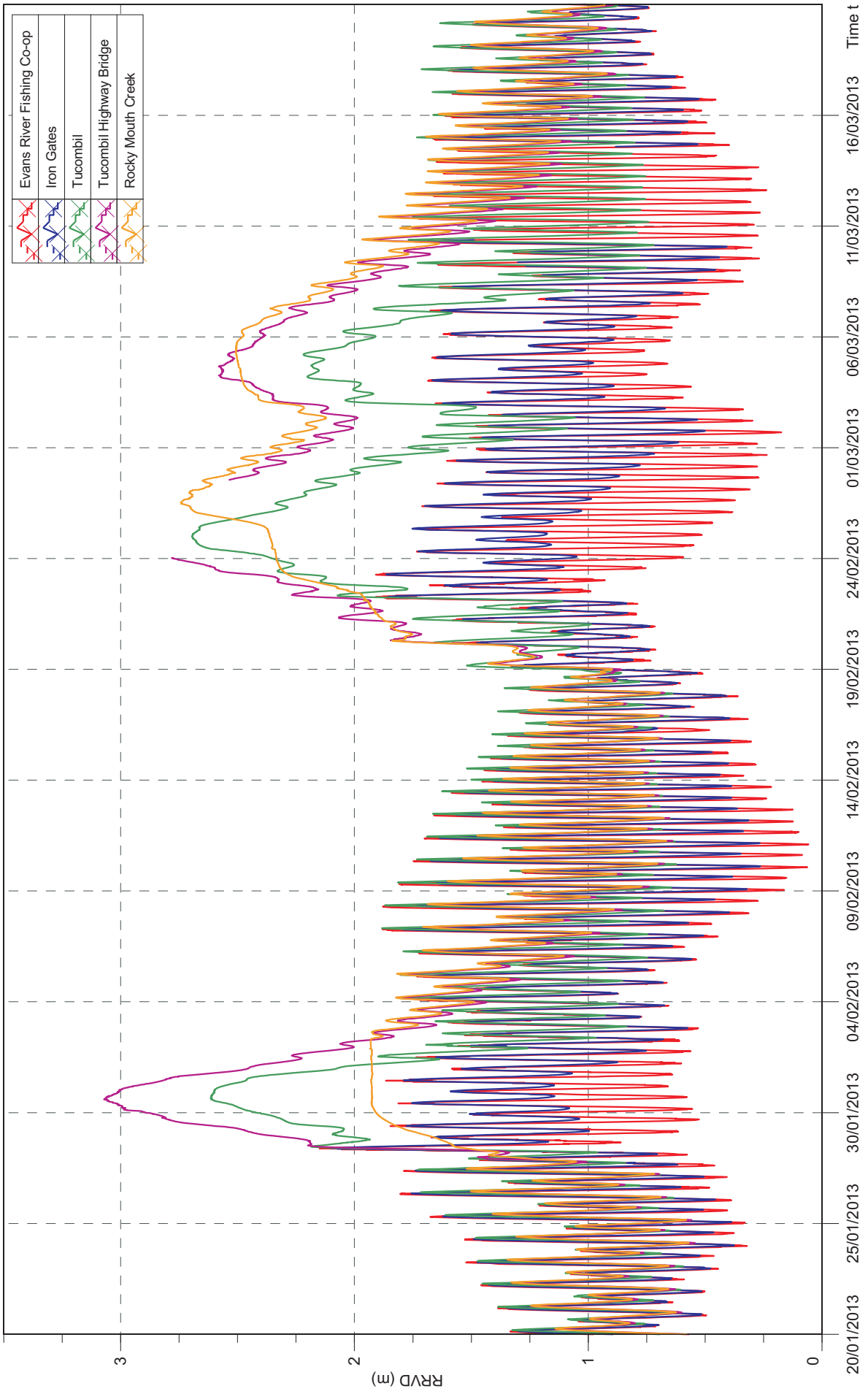
Figure 5.2

DRAWING 2202-05-02.cdr



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RICHMOND RIVER REGION
WATER LEVEL DATA
20 JANUARY-20 MARCH 2013

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Figure 5.3

DRAWING 2202-05-03.cdr

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RICHMOND RIVER REGION
WATER LEVEL AND RAINFALL DATA
20 JANUARY-20 MARCH 2013

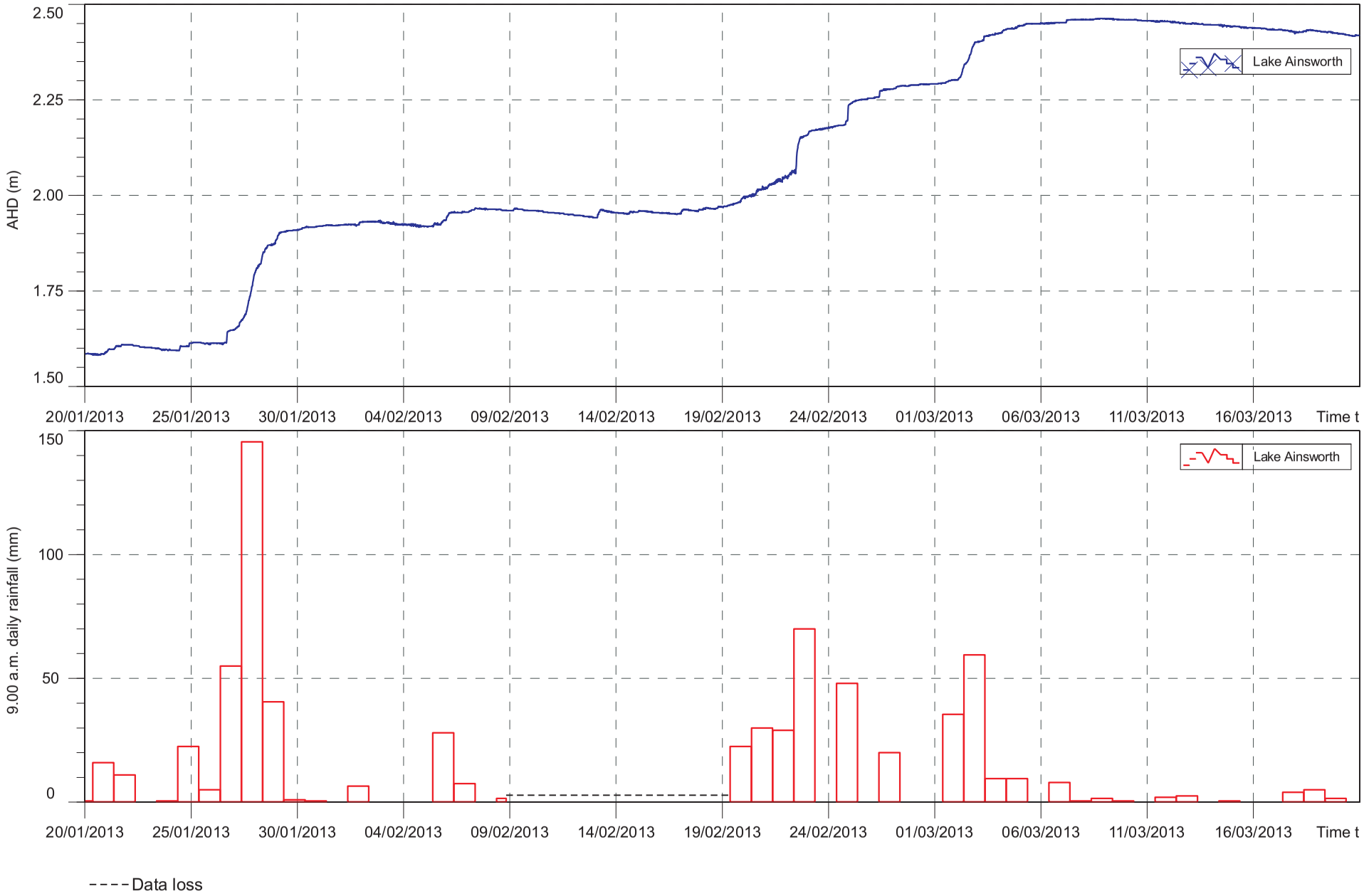

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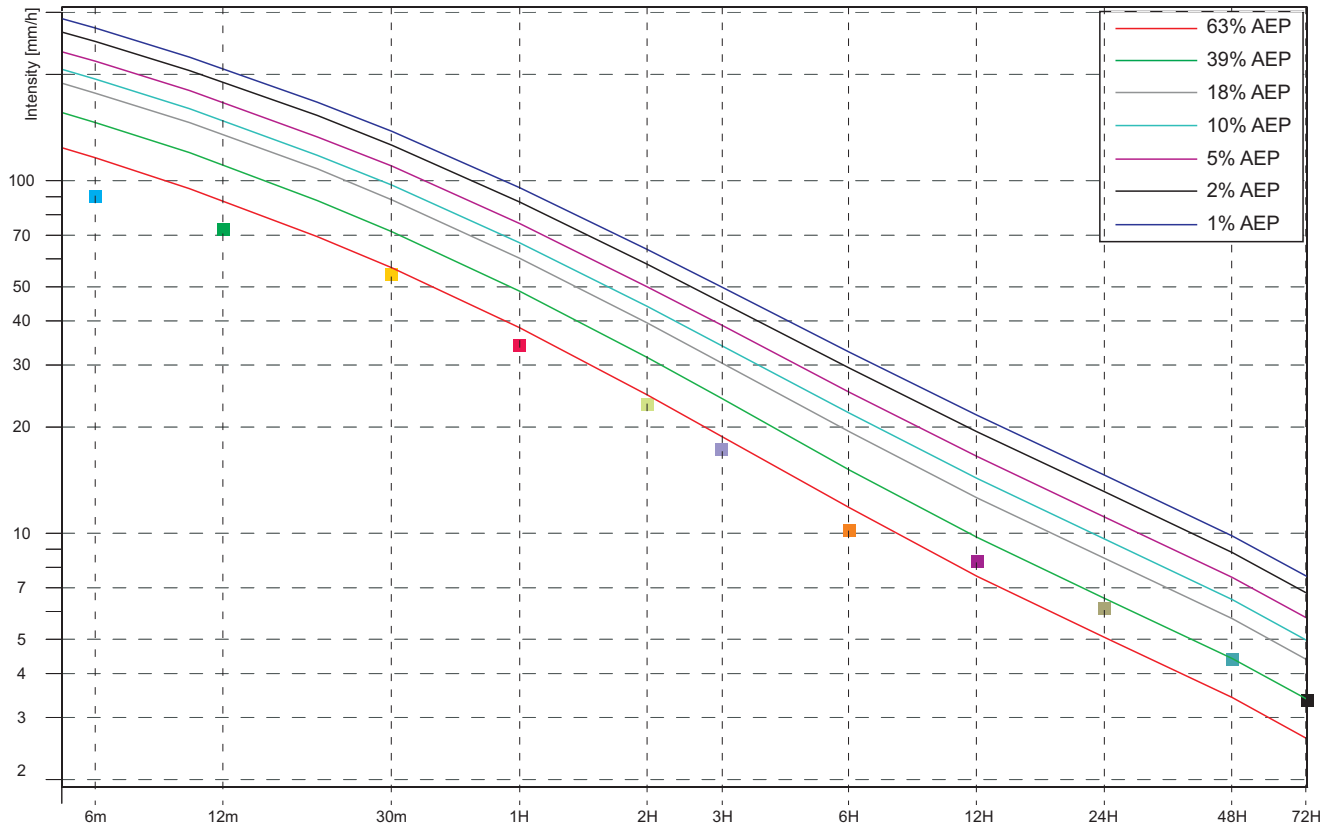
Figure 5.4

DRAWING 2202-05-04.cdr



Duration
(minutes: m, hours: H)
Reference: Australian Rainfall and Runoff 1987

Lake Ainsworth Rainfall Intensity 21 January-21 March 2013*		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	90.00	24/02/2013 21:48
12m	72.50	22/02/2013 11:50
30m	54.00	22/02/2013 11:56
1H	34.00	22/02/2013 12:24
2H	23.25	22/02/2013 13:26
3H	17.33	22/02/2013 13:44
6H	10.17	22/02/2013 16:04
12H	8.29	28/01/2013 1:36
24H	6.12	28/01/2013 11:48
48H	4.40	28/01/2013 12:16
72H	3.36	29/01/2013 4:54

*Data loss 8-19 February 2013

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:
Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

The use of the term 'Average Recurrence Interval' (ARI) can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of Annual Exceedance Probability (AEP). For example, 'a rainfall total of 60mm falling in 3 hours at Cudgera has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year' can be easier to understand than the equivalent statement of 'rainfall total of 60mm in 3 hours has an ARI of 100 years'.

Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml

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LAKE AINSWORTH INTENSITY-FREQUENCY-DURATION
21 JANUARY-21 MARCH 2013

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Figure 5.5
DRAWING 2202-05-05.cdr

6. Clarence River Region

6.1 Clarence River Region Water Level

The locations of water level stations within the Clarence River region are shown in Figure 6.1. The water level data for the period 20 January to 20 March 2013 can be viewed graphically in Figure 6.2. The peak water levels are listed in Table 6.1.

Table 6.2 lists the Bureau of Meteorology flood classification for Grafton, Ulmarra and Maclean. The BoM classification scheme indicates the flood peaks at Grafton and Ulmarra were classified as major during the January and February floods.

Table 6.1 Clarence River Region Flood Peaks

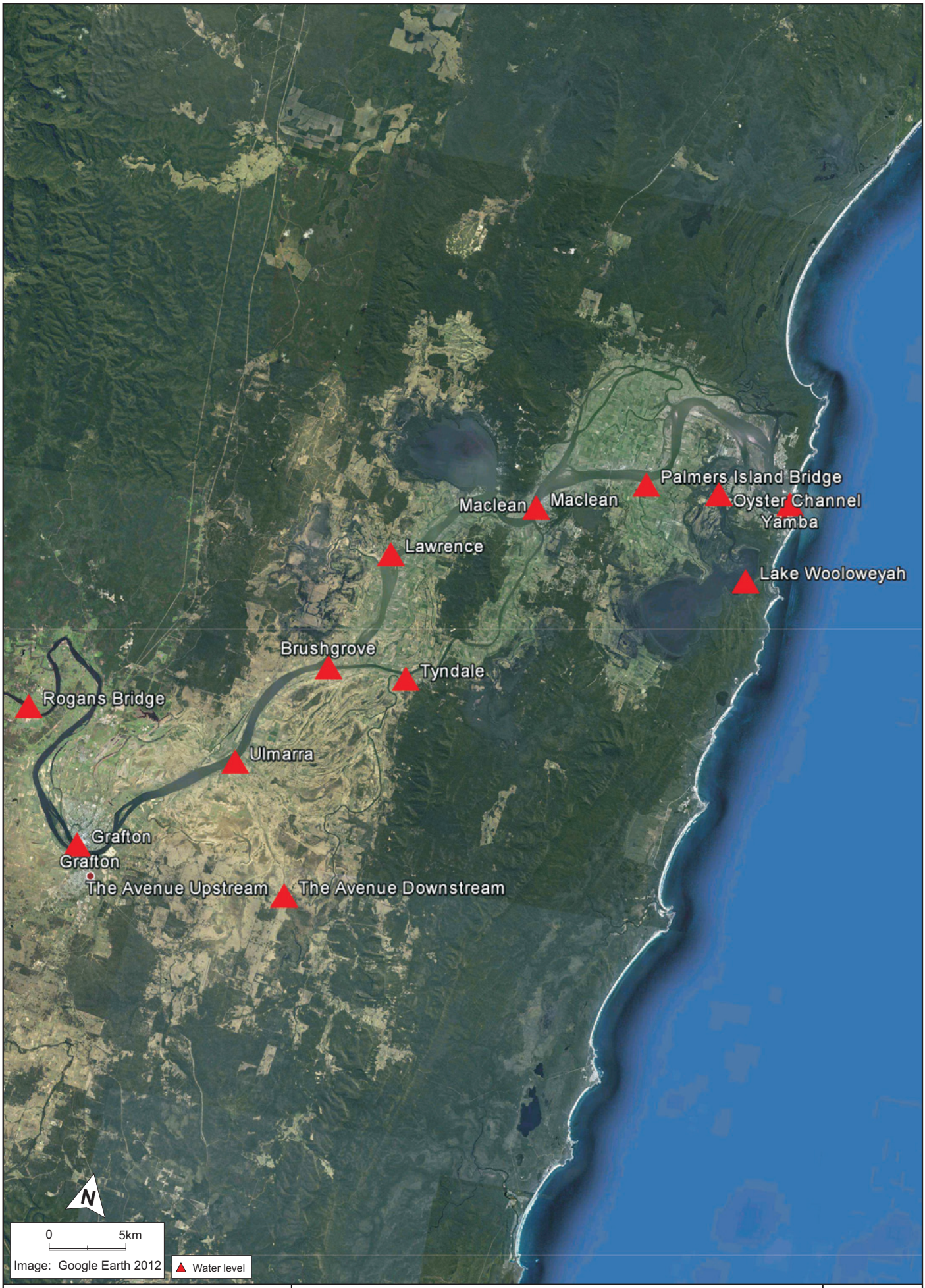
Station	Datum	Peak level (m)	Event 1 Time/Date	Peak level (m)	Event 2 Time/Date	Peak level (m)	Event 3 Time/Date
Yamba	AHD	1.23	1000 30/01/2013	1.10	0730 24/02/2013	0.97	0045 04/03/2013
Oyster Channel	AHD	1.34	1145 30/01/2013	1.07	0900 25/02/2013	0.93	0130 04/03/2013
Palmers Island Bridge	AHD	2.55	1045 30/01/2013	1.95	0830 25/02/2013	1.36	0200 04/03/2013
Maclean	AHD	3.11	1145 30/01/2013	2.42	2245 24/02/2013	1.59	0330 04/03/2013
Lake Wooloweyah	AHD	1.21	0100 31/01/2013	0.97	1100 24/02/2013	0.81	0500 05/03/2013
Lawrence	AHD	4.43	0015 30/01/2013	3.45	1945 24/02/2013	2.19	0930 04/03/2013
Tyndale	AHD	4.39	1845 29/01/2013	3.77	1030 24/02/2013	2.41	0730 04/03/2013
Brushgrove	AHD	4.79	1830 29/01/2013	4.05	0900 24/02/2013	2.54	0745 04/03/2013
Rogans Bridge	AHD	15.42	0745 29/01/2013	10.12	0230 24/02/2013	6.20	0015 04/03/2013
Ulmarra	AHD	6.08	1815 29/01/2013	4.99	0815 24/02/2013	2.96	0600 04/03/2013
Grafton	AHD	8.09	0815 29/01/2013	6.28	0630 24/02/2013	3.66	0400 04/03/2013
The Avenue Upstream	AHD	4.02	0715 30/01/2013	3.06	1745 25/02/2013	2.40	0430 05/03/2013
The Avenue Downstream	AHD	4.01	0745 30/01/2013	3.07	0715 25/02/2013	2.18	2315 04/03/2013

AHD Australian Height Datum

Table 6.2 BoM Flood Gauge Classification for Clarence River Region

Station	Classification			Peak (m)	Classification
	Minor	Moderate	Major		
	Water Level AHD (m)				
Grafton	2.1	3.6	5.4	8.09 (29/01/2013)	Major
				6.29 (24/02/2013)	Major
				3.66 (04/03/2013)	Moderate
Ulmarra	2.1	3.4	4.9	6.08 (29/01/2013)	Major
				4.99 (24/02/2013)	Major
				2.96 (04/03/2013)	Minor
Maclean	1.6	2.2	2.5	3.11 (30/01/2013)	Major
				2.42 (24/02/2013)	Moderate
				1.59 (04/03/2013)	Below Minor

AHD Australian Height Datum



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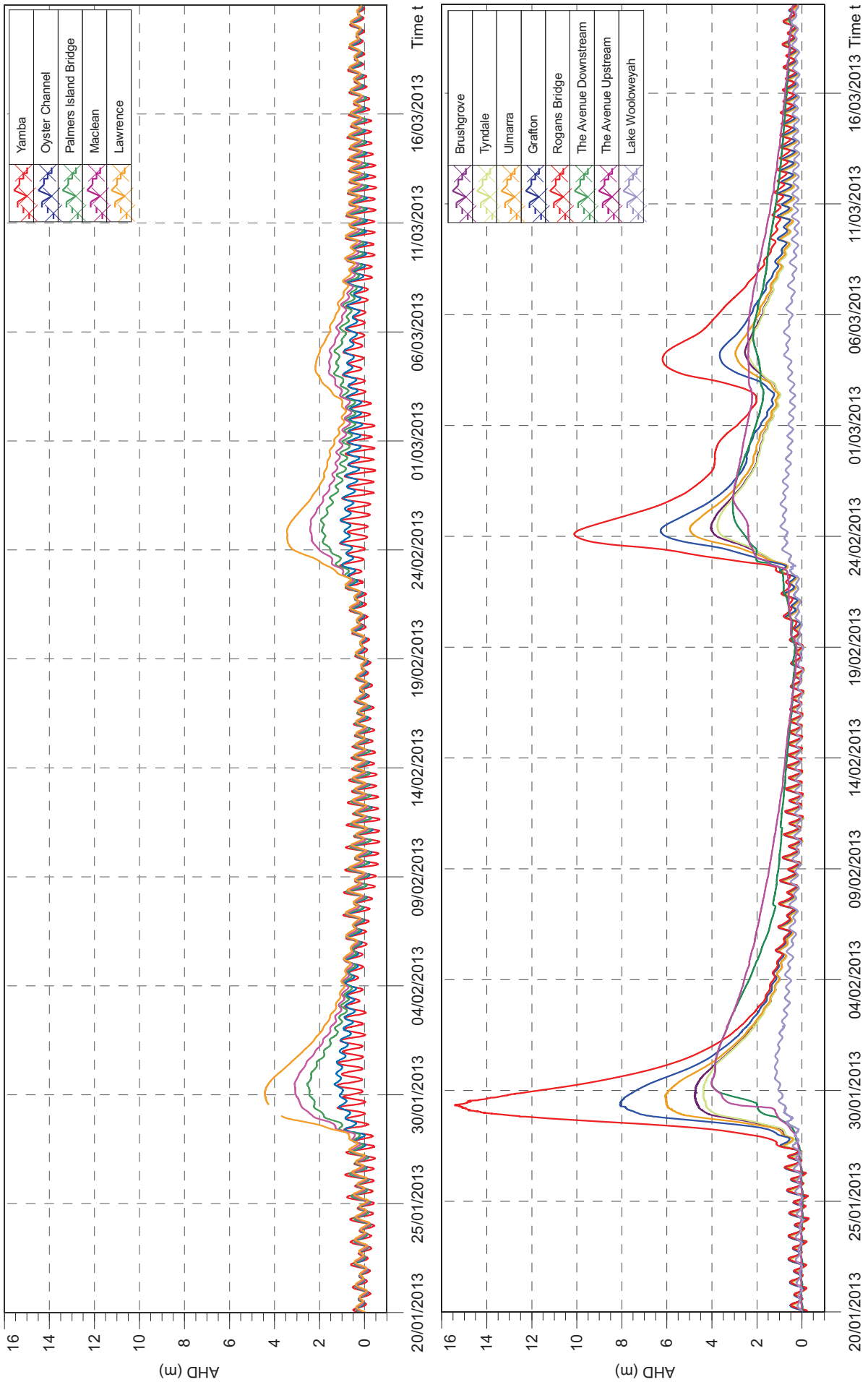
STATION LOCATIONS
CLARENCE RIVER REGION

MHL Report 2202

Figure 6.1

DRAWING 2202-06-01.cdr



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CLARENCE RIVER REGION
WATER LEVEL DATA
20 JANUARY-20 MARCH 2013

MHL Report 2202

Figure 6.2

DRAWING 2202-06-02.cdr

7. Woolgoolga Region

7.1 Woolgoolga Region Water Level

The locations of water level stations within the Woolgoolga region are shown in Figure 7.1. The water level data for the period 20 January to 20 March 2013 can be viewed graphically in Figure 7.2. The peak water levels are listed in Table 7.1.

Table 7.1 Woolgoolga Region Flood Peaks

Station	Datum	Peak level (m)	Event 1 Time/Date	Peak level (m)	Event 2 Time/Date	Peak level (m)	Event 3 Time/Date
Wooli Caravan Park	AHD	1.15	1000 29/01/2013	1.61	0730 23/02/2013	-	-
Wooli Entrance	AHD	1.08	0930 28/01/2013	1.25	0715 23/02/2013	-	-
Red Rock	AHD	1.30	0845 28/01/2013	1.60	2115 22/02/2013	-	-
Woolgoolga Lake	AHD	1.59	0900 28/01/2013	1.97	1830 22/02/2013	-	-
Woolgoolga	CTF	1.67	1300 28/01/2013	3.13	1800 22/02/2013	0.84	1545 02/03/2013
Moonee Creek	AHD	1.49	1000 28/01/2013	1.72	1900 22/02/2013	-	-

- No discernible flood hydrograph recorded at these stations
AHD Australian Height Datum, CTF Cease to Flow

7.2 Woolgoolga Region Rainfall

9.00 a.m. daily rainfall totals are displayed in Figure 7.2 and Table 7.2 for the period 24 January to 5 March 2013. The rainfall data and intensities are displayed graphically in Figure 7.3.

Table 7.2 Woolgoolga Region Daily Rainfall Totals

Date	Wooli Caravan Park (mm)
24/01/2013	12.0
25/01/2013	9.0
26/01/2013	17.5
27/01/2013	77.0
28/01/2013	159.5
29/01/2013	69.5
30/01/2013	0.0
31/01/2013	0.0
01/02/2013	0.0
02/02/2013	16.5
03/02/2013	2.0
04/02/2013	0.0
05/02/2013	4.0
06/02/2013	12.0
07/02/2013	5.0
08/02/2013	1.0
09/02/2013	3.0
10/02/2013	0.0
11/02/2013	0.0
12/02/2013	0.0
13/02/2013	11.5
14/02/2013	0.5
15/02/2013	4.5
16/02/2013	3.0
17/02/2013	10.5
18/02/2013	24.5
19/02/2013	34.0
20/02/2013	12.0
21/02/2013	6.0
22/02/2013	23.5
23/02/2013	129.0
24/02/2013	4.5
25/02/2013	7.0
26/02/2013	0.5
27/02/2013	5.0
28/02/2013	2.0
01/03/2013	4.5
02/03/2013	58.0
03/03/2013	76.5
04/03/2013	2.5
05/03/2013	5.5
Total	**813.0**

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STATION LOCATIONS
WOOLGOOLGA REGION

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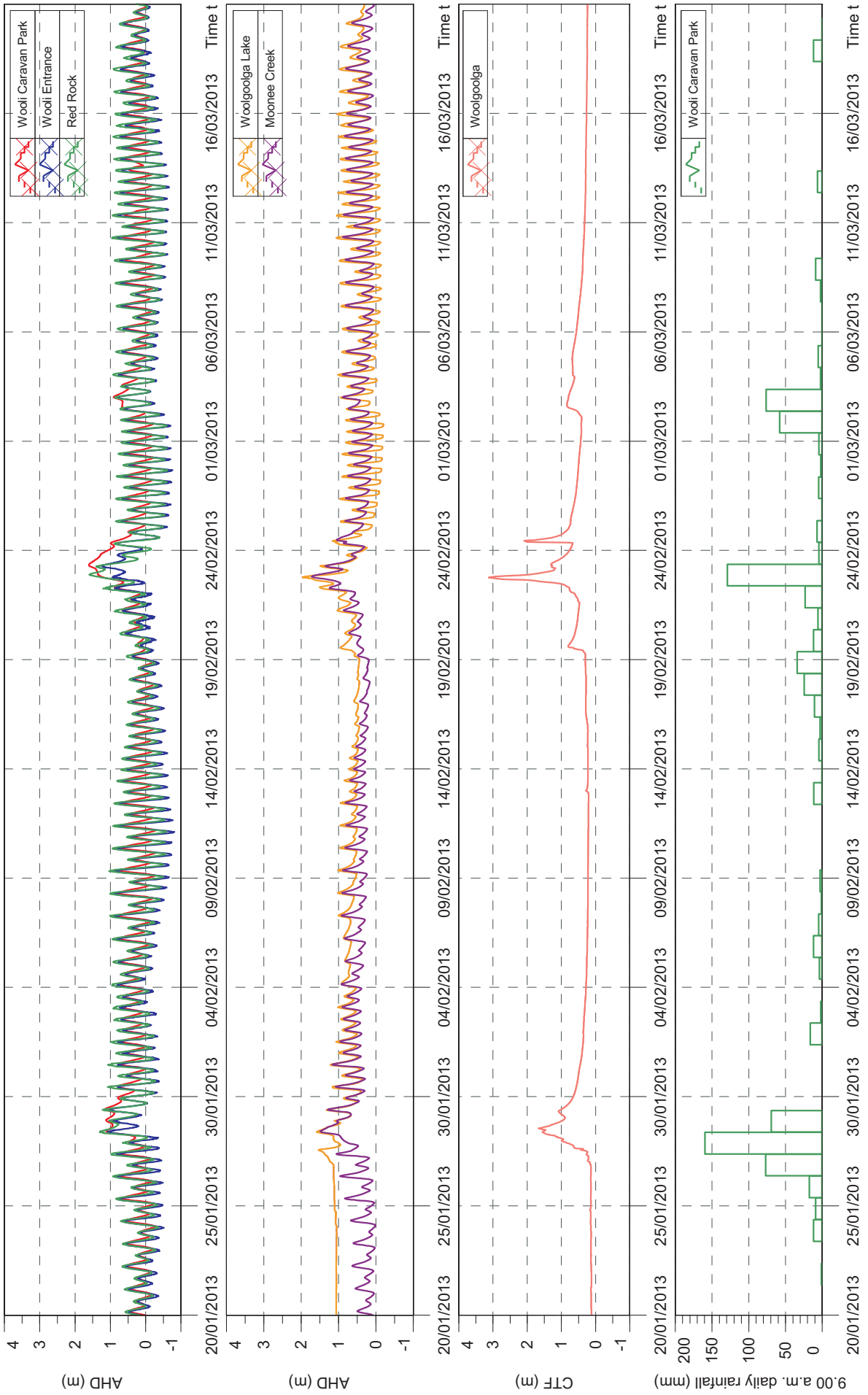
Figure 7.1

DRAWING 2202-07-01.cdr



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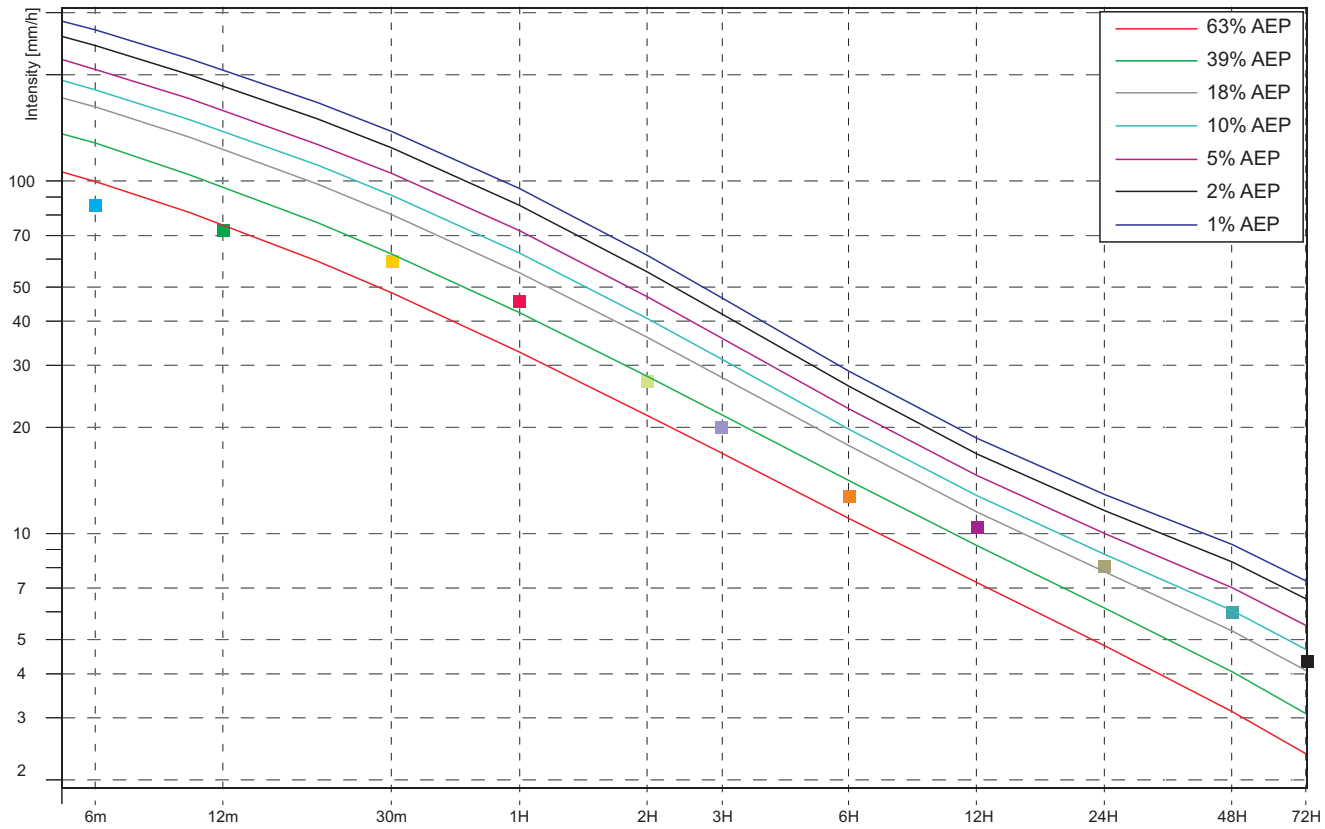
WOOLGOOLGA REGION
WATER LEVEL AND RAINFALL DATA
20 JANUARY-20 MARCH 2013

MHL Report 2202

Figure 7.2

DRAWING 2202-07-02.cdr



Duration
(minutes: m, hours: H)
Reference: Australian Rainfall and Runoff 1987

Wooli Rainfall Intensity 21 January-21 March 2013		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	85.00	23/02/2013 0:38
12m	72.50	2/03/2013 9:34
30m	59.00	2/03/2013 9:48
1H	45.50	2/03/2013 10:04
2H	27.00	2/03/2013 10:18
3H	20.00	2/03/2013 10:14
6H	12.75	2/03/2013 12:30
12H	10.37	28/01/2013 11:46
24H	8.08	28/01/2013 11:46
48H	5.98	28/01/2013 17:10
72H	4.33	29/01/2013 6:32

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:
Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

The use of the term 'Average Recurrence Interval' (ARI) can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of Annual Exceedance Probability (AEP). For example, 'a rainfall total of 60mm falling in 3 hours at Cudgera has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year' can be easier to understand than the equivalent statement of 'rainfall total of 60mm in 3 hours has an ARI of 100 years'.

Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml

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WOOLI CARAVAN PARK
INTENSITY-FREQUENCY-DURATION
21 JANUARY-21 MARCH 2013

MHL Report 2202
Figure 7.3
DRAWING 2202-07-03.cdr

8. Coffs Harbour Region

8.1 Coffs Harbour Region Water Level

The locations of water level stations within the Coffs Harbour region are shown in Figure 8.1. The water level data for the period 20 January to 20 March 2013 can be viewed graphically in Figure 8.2. The peak water levels are listed in Table 8.1.

Table 8.1 Coffs Harbour Region Flood Peaks

Station	Datum	Peak level (m)	Event 1 Time/Date	Peak level (m)	Event 2 Time/Date	Peak level (m)	Event 3 Time/Date
Coffs Creek Highway Bridge	AHD	2.76	1045 28/01/2013	2.52	1745 22/02/2013	1.01	0115 04/03/2013
Newports Creek	AHD	1.58	1300 28/01/2013	1.50	2030 22/02/3013	1.01	0030 03/03/2013
Boambee	AHD	1.61	1045 28/01/2013	1.51	1930 22/02/2013	1.05	0030 03/03/2013
Boambee Entrance	AHD	1.33	1015 29/01/2013	1.37	0615 23/02/2013	0.95	0030 03/03/2013

AHD Australian Height Datum

8.2 Coffs Harbour Region Rainfall

9.00 a.m. daily rainfall totals are displayed in Figure 8.3 and Table 8.2 for the period 24 January to 5 March 2013. The rainfall data and intensities are displayed graphically in Figures 8.4 to 8.9.

Table 8.2 Coffs Harbour Region Daily Rainfall Totals

Date	Perry Drive (mm)	Shepards Lane (mm)	Red Hill (mm)	Newports Creek (mm)	Middle Boambee (mm)	North Bonville (mm)
24/01/2013	7.5	1.5	6.5	2.5	4.0	4.5
25/01/2013	4.0	3.0	1.5	1.0	1.0	0.0
26/01/2013	7.5	8.5	6.5	10.5	9.5	6.0
27/01/2013	59.5	65.0	59.0	45.5	47.5	45.0
28/01/2013	235.5	242.0	241.5	252.0	265.0	201.0
29/01/2013	152.5	165.5	148.0	124.0	120.5	85.5
30/01/2013	3.0	1.0	1.5	0.5	0.0	0.0
31/01/2013	0.0	0.0	0.0	0.0	0.0	0.0
01/02/2013	0.0	0.0	0.0	0.0	0.0	0.0
02/02/2013	14.0	15.0	19.0	20.5	18.0	20.0
03/02/2013	4.0	4.5	10.5	7.0	0.0	0.0
04/02/2013	0.0	0.0	0.0	0.0	0.0	0.0

Date	Perry Drive (mm)	Shepards Lane (mm)	Red Hill (mm)	Newports Creek (mm)	Middle Boambee (mm)	North Bonville (mm)
05/02/2013	4.0	3.5	3.5	4.0	5.0	2.5
06/02/2013	2.5	3.0	1.0	1.0	3.5	2.5
07/02/2013	2.5	3.5	2.5	2.0	3.0	2.5
08/02/2013	0.0	0.0	4.5	0.0	0.0	0.0
09/02/2013	0.0	0.0	0.0	0.0	0.0	0.0
10/02/2013	0.0	0.5	0.0	0.0	0.5	0.0
11/02/2013	0.0	0.0	0.0	0.0	0.0	0.0
12/02/2013	0.0	0.0	0.0	0.0	0.0	0.0
13/02/2013	17.0	15.5	17.5	11.0	13.5	19.5
14/02/2013	3.5	6.0	5.0	4.5	7.5	4.5
15/02/2013	16.5	19.5	14.5	7.0	8.5	12.0
16/02/2013	9.0	4.0	3.5	14.5	16.0	16.0
17/02/2013	21.0	16.0	11.0	11.5	13.0	10.5
18/02/2013	5.5	5.0	7.0	5.5	9.5	36.0
19/02/2013	6.5	9.0	8.0	3.0	3.5	3.0
20/02/2013	49.5	45.5	45.5	47.0	70.5	64.0
21/02/2013	12.0	13.0	12.5	22.0	13.0	25.5
22/02/2013	57.0	63.0	50.0	68.0	104.0	62.0
23/02/2013	130.0	150.5	156.0	149.0	167.0	174.5
24/02/2013	3.0	3.5	1.0	0.5	0.5	8.5
25/02/2013	37.5	58.0	57.5	51.0	48.0	47.5
26/02/2013	3.0	5.0	4.0	5.0	9.5	4.5
27/02/2013	6.5	3.5	3.0	4.5	2.0	2.5
28/02/2013	5.5	3.0	3.0	6.0	5.5	4.0
01/03/2013	0.0	0.0	0.0	0.0	0.5	0.0
02/03/2013	24.5	27.0	24.5	21.5	21.5	31.0
03/03/2013	26.0	30.0	38.0	51.5	59.5	98.5
04/03/2013	18.5	20.5	21.5	26.5	25.0	19.5
05/03/2013	3.5	4.5	5.0	1.5	3.0	4.5
Total	**952.0**	**1018.5**	**993.5**	**981.5**	**1078.5**	**1017.5**

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STATION LOCATIONS
COFFS HARBOUR REGION

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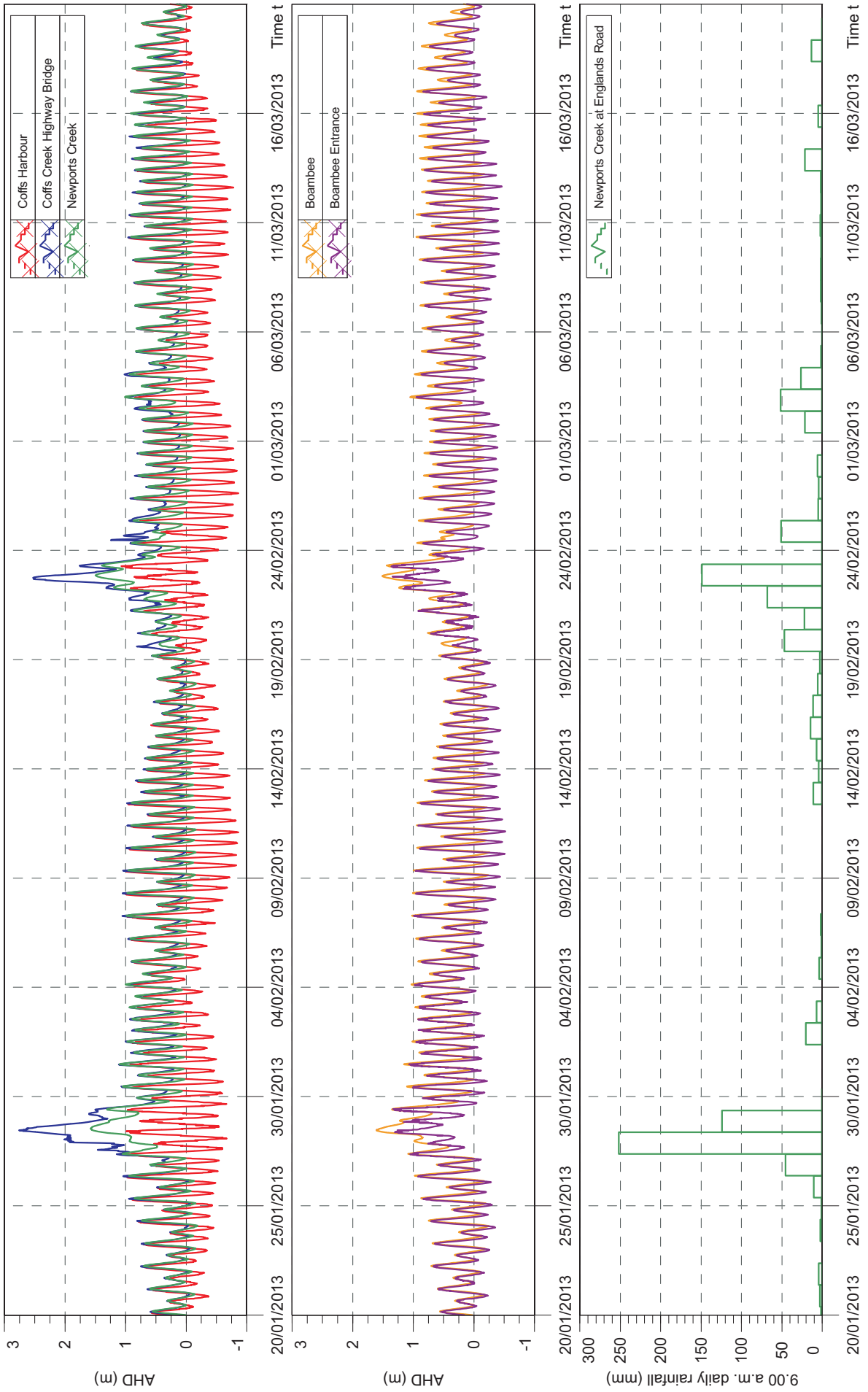
Figure 8.1

DRAWING 2202-08-01.cdr



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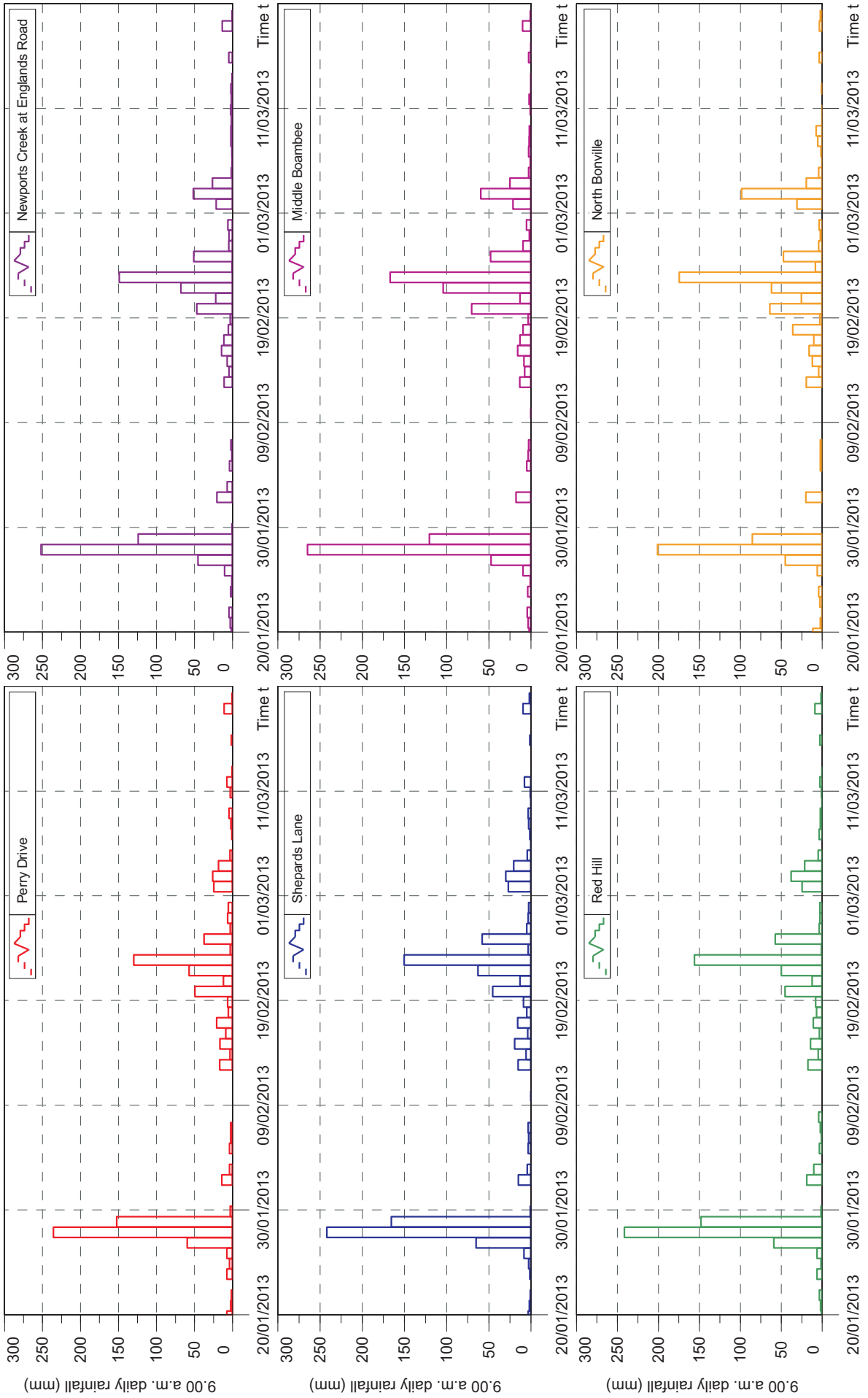
COFFS HARBOUR REGION
WATER LEVEL AND RAINFALL DATA
20 JANUARY-20 MARCH 2013

MHL Report 2202

Figure 8.2

DRAWING 2202-08-02.cdr



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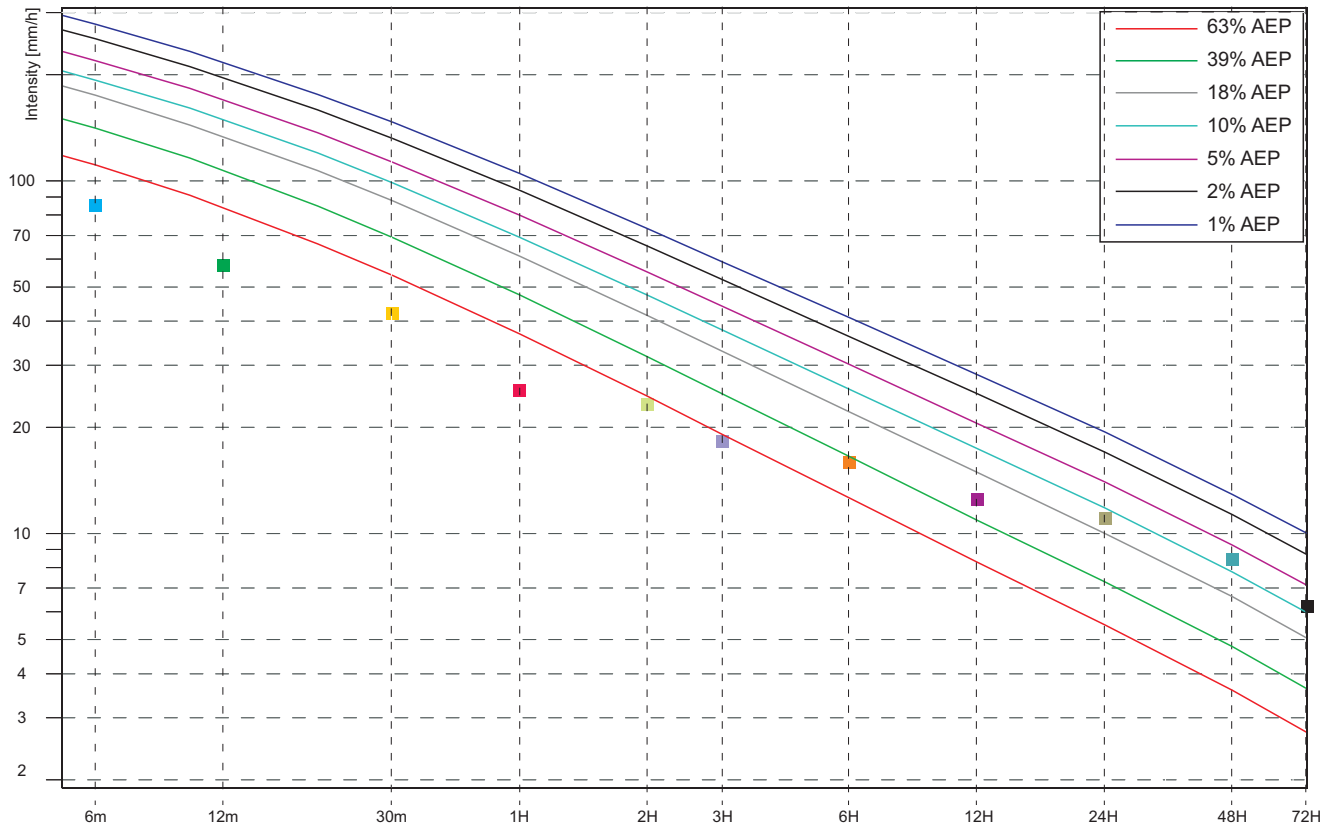
COFFS HARBOUR REGION
RAINFALL DATA
20 JANUARY-20 MARCH 2013

MHL Report 2202

Figure 8.3

DRAWING 2202-08-03.cdr



Duration
(minutes: m, hours: H)

Reference: Australian Rainfall and Runoff 1987

Perry Drive Rainfall Intensity 21 January-21 March 2013		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	85.00	12/02/2013 21:52
12m	57.50	12/02/2013 21:54
30m	42.00	27/01/2013 12:54
1H	25.50	27/01/2013 21:18
2H	23.25	27/01/2013 12:56
3H	18.17	28/01/2013 9:48
6H	15.83	28/01/2013 12:00
12H	12.50	28/01/2013 12:46
24H	11.00	28/01/2013 10:56
48H	8.41	29/01/2013 5:56
72H	6.22	29/01/2013 7:20

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:

Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

The use of the term 'Average Recurrence Interval' (ARI) can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of Annual Exceedance Probability (AEP). For example, 'a rainfall total of 60mm falling in 3 hours at Cudgera has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year' can be easier to understand than the equivalent statement of 'rainfall total of 60mm in 3 hours has an ARI of 100 years'.

Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml

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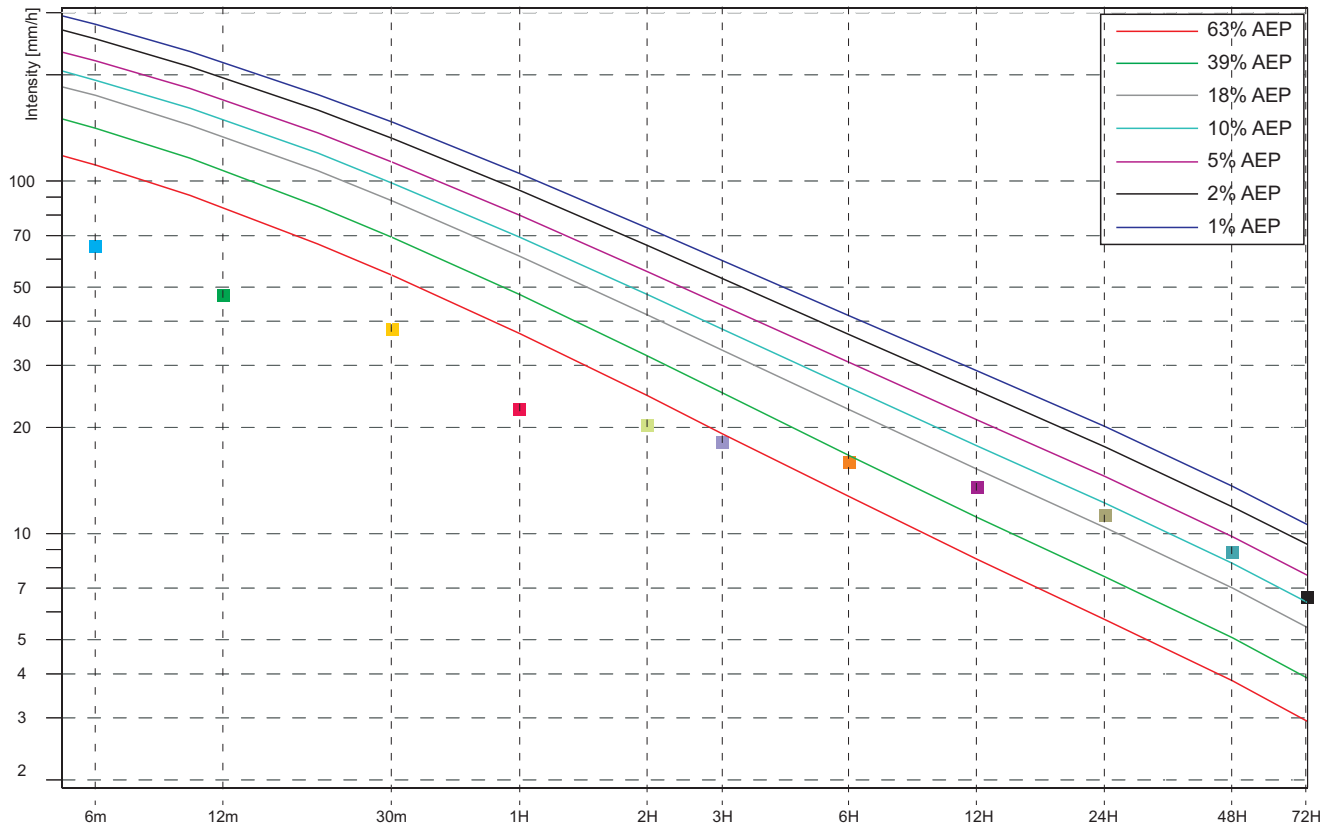
PERRY DRIVE
INTENSITY-FREQUENCY-DURATION
21 JANUARY-21 MARCH 2013

MHL Report 2202

Figure 8.4

DRAWING 2202-08-04.cdr



Duration
(minutes: m, hours: H)
Reference: Australian Rainfall and Runoff 1987

Shepards Lane Rainfall Intensity 21 January-21 March 2013		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	65.00	1/02/2013 20:38
12m	47.50	22/02/2013 16:00
30m	38.00	27/01/2013 12:56
1H	22.50	22/02/2013 16:32
2H	20.25	27/01/2013 12:56
3H	18.17	28/01/2013 9:46
6H	15.92	28/01/2013 12:00
12H	13.50	28/01/2013 12:40
24H	11.27	28/01/2013 17:38
48H	8.82	29/01/2013 5:42
72H	6.58	29/01/2013 12:54

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:
Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

The use of the term 'Average Recurrence Interval' (ARI) can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of Annual Exceedance Probability (AEP). For example, 'a rainfall total of 60mm falling in 3 hours at Cudgera has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year' can be easier to understand than the equivalent statement of 'rainfall total of 60mm in 3 hours has an ARI of 100 years'.

Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml

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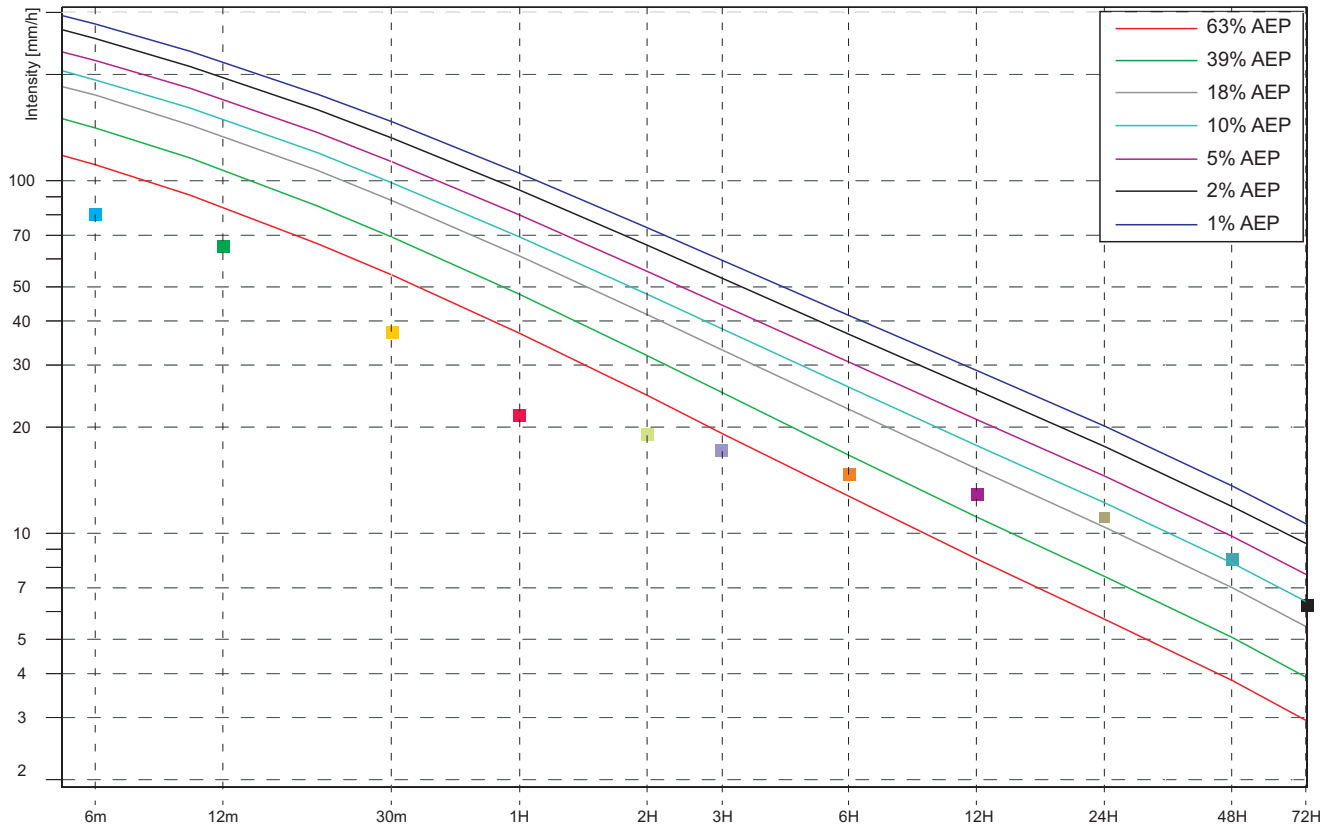
SHEPARDS LANE
INTENSITY-FREQUENCY-DURATION
21 JANUARY-21 MARCH 2013

MHL Report 2202
Figure 8.5
DRAWING 2202-08-05.cdr



Duration
(minutes: m, hours: H)
Reference: Australian Rainfall and Runoff 1987

Red Hill Rainfall Intensity 21 January-21 March 2013		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	80.00	1/02/2013 20:38
12m	65.00	1/02/2013 20:42
30m	37.00	27/01/2013 12:58
1H	21.50	27/01/2013 13:10
2H	19.00	27/01/2013 13:00
3H	17.17	28/01/2013 9:48
6H	14.67	28/01/2013 11:58
12H	12.92	28/01/2013 12:40
24H	11.06	28/01/2013 12:24
48H	8.45	29/01/2013 5:44
72H	6.24	29/01/2013 12:50

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:
Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

The use of the term 'Average Recurrence Interval' (ARI) can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of Annual Exceedance Probability (AEP). For example, 'a rainfall total of 60mm falling in 3 hours at Cudgera has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year' can be easier to understand than the equivalent statement of 'rainfall total of 60mm in 3 hours has an ARI of 100 years'.

Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml

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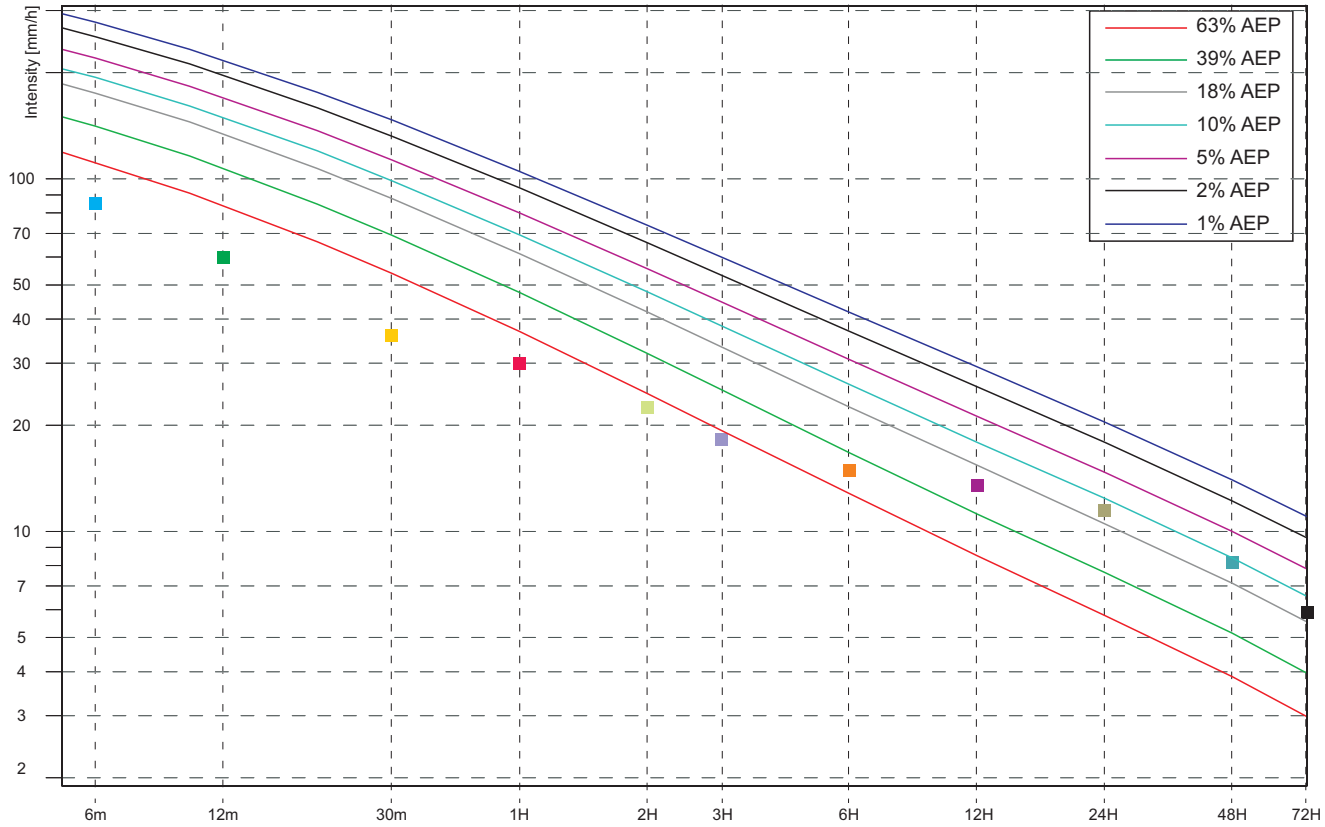
RED HILL
INTENSITY-FREQUENCY-DURATION
21 JANUARY-21 MARCH 2013

MHL Report 2202
Figure 8.6
DRAWING 2202-08-06.cdr



Duration
(minutes: m, hours: H)
Reference: Australian Rainfall and Runoff 1987

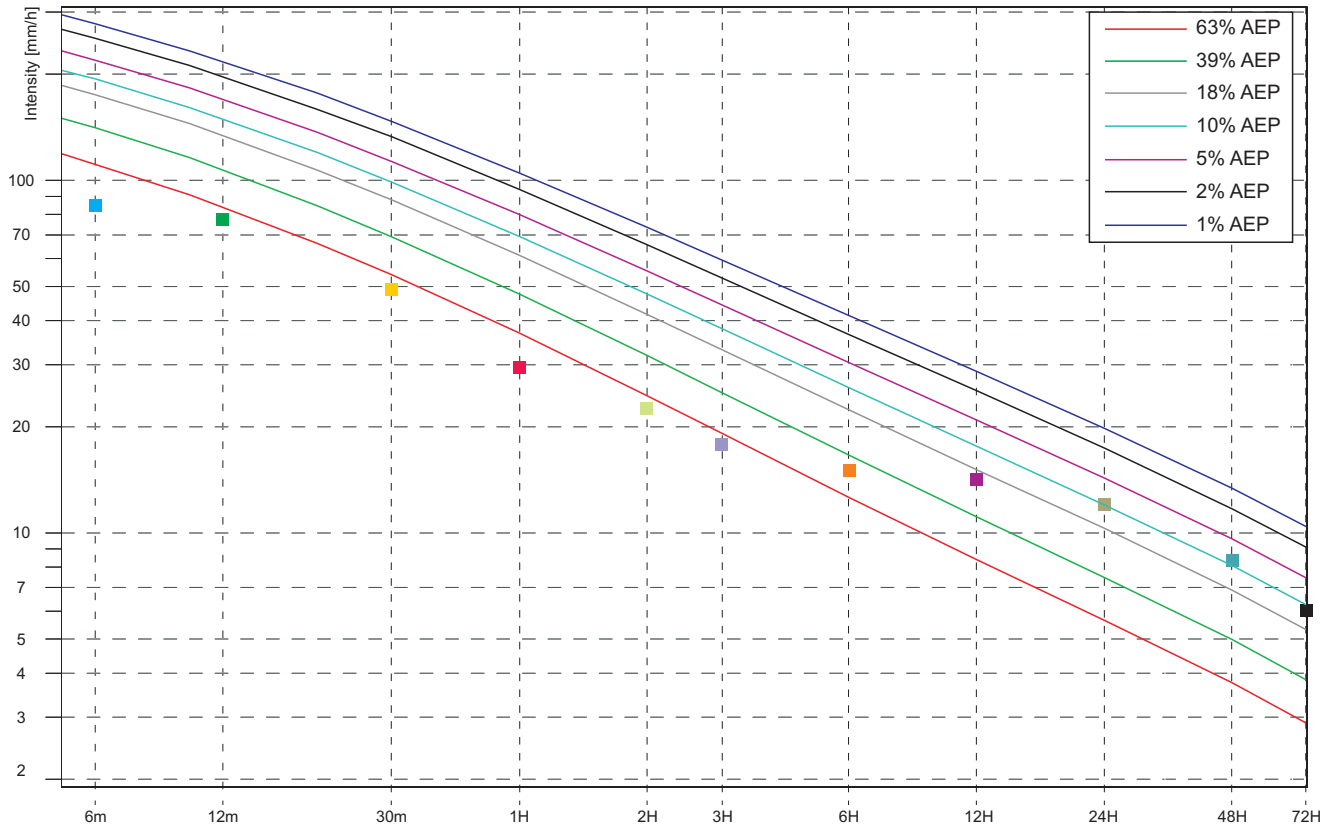
Newports Creek Rainfall Intensity 21 January-21 March 2013		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	85.00	28/01/2013 2:06
12m	60.00	28/01/2013 2:08
30m	36.00	27/01/2013 12:58
1H	30.00	27/01/2013 21:22
2H	22.50	27/01/2013 22:28
3H	18.17	27/01/2013 22:46
6H	14.92	28/01/2013 2:22
12H	13.46	28/01/2013 8:22
24H	11.48	28/01/2013 11:06
48H	8.15	29/01/2013 5:38
72H	5.90	29/01/2013 5:38

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:

Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

The use of the term 'Average Recurrence Interval' (ARI) can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of Annual Exceedance Probability (AEP). For example, 'a rainfall total of 60mm falling in 3 hours at Cudgera has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year' can be easier to understand than the equivalent statement of 'rainfall total of 60mm in 3 hours has an ARI of 100 years'.

Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml



Duration
(minutes: m, hours: H)
Reference: Australian Rainfall and Runoff 1987

Middle Boambee Rainfall Intensity 21 January-21 March 2013		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	85.00	21/02/2013 17:20
12m	77.50	21/02/2013 17:28
30m	49.00	21/02/2013 17:46
1H	29.50	21/02/2013 18:08
2H	22.50	27/01/2013 22:30
3H	17.83	27/01/2013 22:48
6H	15.08	28/01/2013 2:22
12H	14.17	28/01/2013 8:22
24H	12.02	28/01/2013 11:06
48H	8.36	29/01/2013 5:34
72H	6.03	29/01/2013 5:34

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:
Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

The use of the term 'Average Recurrence Interval' (ARI) can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of Annual Exceedance Probability (AEP). For example, 'a rainfall total of 60mm falling in 3 hours at Cudgera has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year' can be easier to understand than the equivalent statement of 'rainfall total of 60mm in 3 hours has an ARI of 100 years'.

Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml

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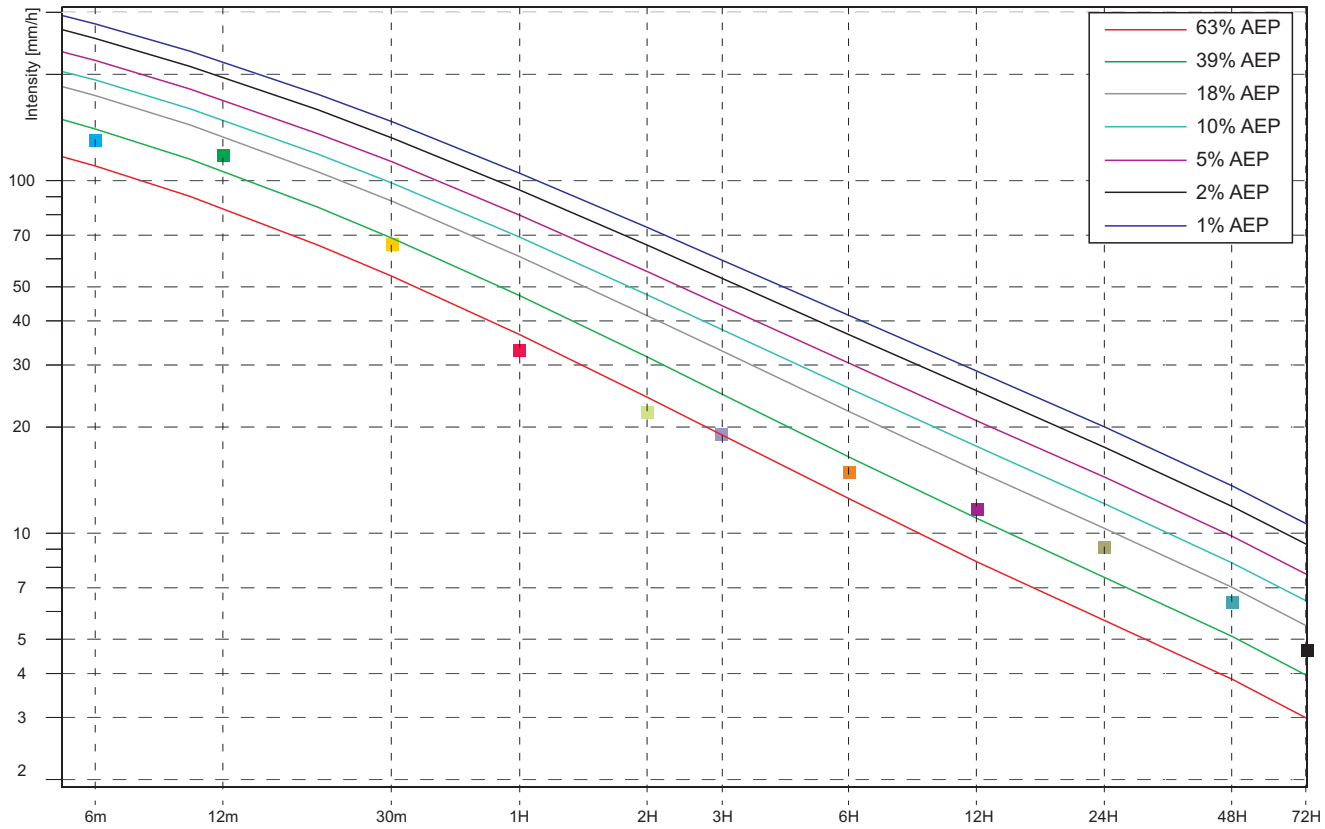
MIDDLE BOAMBEE
INTENSITY-FREQUENCY-DURATION
21 JANUARY-21 MARCH 2013

MHL Report 2202
Figure 8.8
DRAWING 2202-08-08.cdr



Duration
(minutes: m, hours: H)
Reference: Australian Rainfall and Runoff 1987

North Bonville Rainfall Intensity 21 January-21 March 2013		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	130.00	17/02/2013 17:14
12m	117.50	17/02/2013 17:14
30m	66.00	17/02/2013 17:26
1H	33.00	17/02/2013 17:26
2H	22.00	22/02/2013 14:44
3H	19.00	22/02/2013 14:42
6H	14.83	22/02/2013 16:40
12H	11.67	22/02/2013 19:56
24H	9.08	28/01/2013 11:12
48H	6.35	28/01/2013 21:46
72H	4.64	29/01/2013 5:54

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:
Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

The use of the term 'Average Recurrence Interval' (ARI) can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of Annual Exceedance Probability (AEP). For example, 'a rainfall total of 60mm falling in 3 hours at Cudgera has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year' can be easier to understand than the equivalent statement of 'rainfall total of 60mm in 3 hours has an ARI of 100 years'.

Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml

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NORTH BONVILLE
INTENSITY-FREQUENCY-DURATION
21 JANUARY-21 MARCH 2013

MHL Report 2202
Figure 8.9
DRAWING 2202-08-09.cdr

9. Bellinger River Region

9.1 Bellinger River Region Water Level

The locations of water level stations within the Bellinger River region are shown in Figure 9.1. The water level data for the period 20 January to 20 March 2013 can be viewed graphically in Figure 9.2. The peak water levels are listed in Table 9.1.

Table 9.2 lists the Bureau of Meteorology flood classification for Bellingen Bridge and Urunga. The BoM classification scheme indicates the flood peaks for Bellingen Bridge were classified as minor, major and minor floods during the January, February and March floods, respectively.

Table 9.1 Bellinger River Region Flood Peaks

Station	Datum	Peak level (m)	Event 1 Time/Date	Peak level (m)	Event 2 Time/Date	Peak level (m)	Event 3 Time/Date
Bonville	AHD	2.08	1615 28/01/2013	1.96	2045 22/02/2013	1.27	0030 03/03/2013
Repton	AHD	1.90	2215 28/01/2013	3.19	1215 23/02/2013	1.13	0100 03/03/2013
Bellingen Bridge	AHD	6.55	1830 28/01/2013	8.87	0415 23/02/2013	4.24	1015 03/03/13
Urunga	AHD	1.42	1000 28/01/2013	2.04	0730 23/02/2013	-	-
Upstream Newry Island	AHD	1.60	1100 28/01/2013	2.63	0815 23/02/2013	-	-
Kooroowi	Assumed	3.79	1315 28/01/2013	8.66	2330 22/02/2013	3.40	0515 03/03/2013

- No discernible flood hydrograph recorded at these stations
AHD Australian Height Datum

Table 9.2 BoM Flood Gauge Classification for Bellinger Region

Station	Classification			Peak (m)	Classification
	Minor	Moderate	Major		
	Water Level AHD (m)				
Bellingen Bridge	3.7	6.7	8.2	6.55 (28/01/2013)	Minor
				8.87 (23/02/2013)	Major
				4.24 (03/03/2013)	Minor
Urunga	1.5	2.0	2.4	1.42 (28/01/2013)	Below Minor
				2.04 (23/02/2013)	Moderate
				-	-

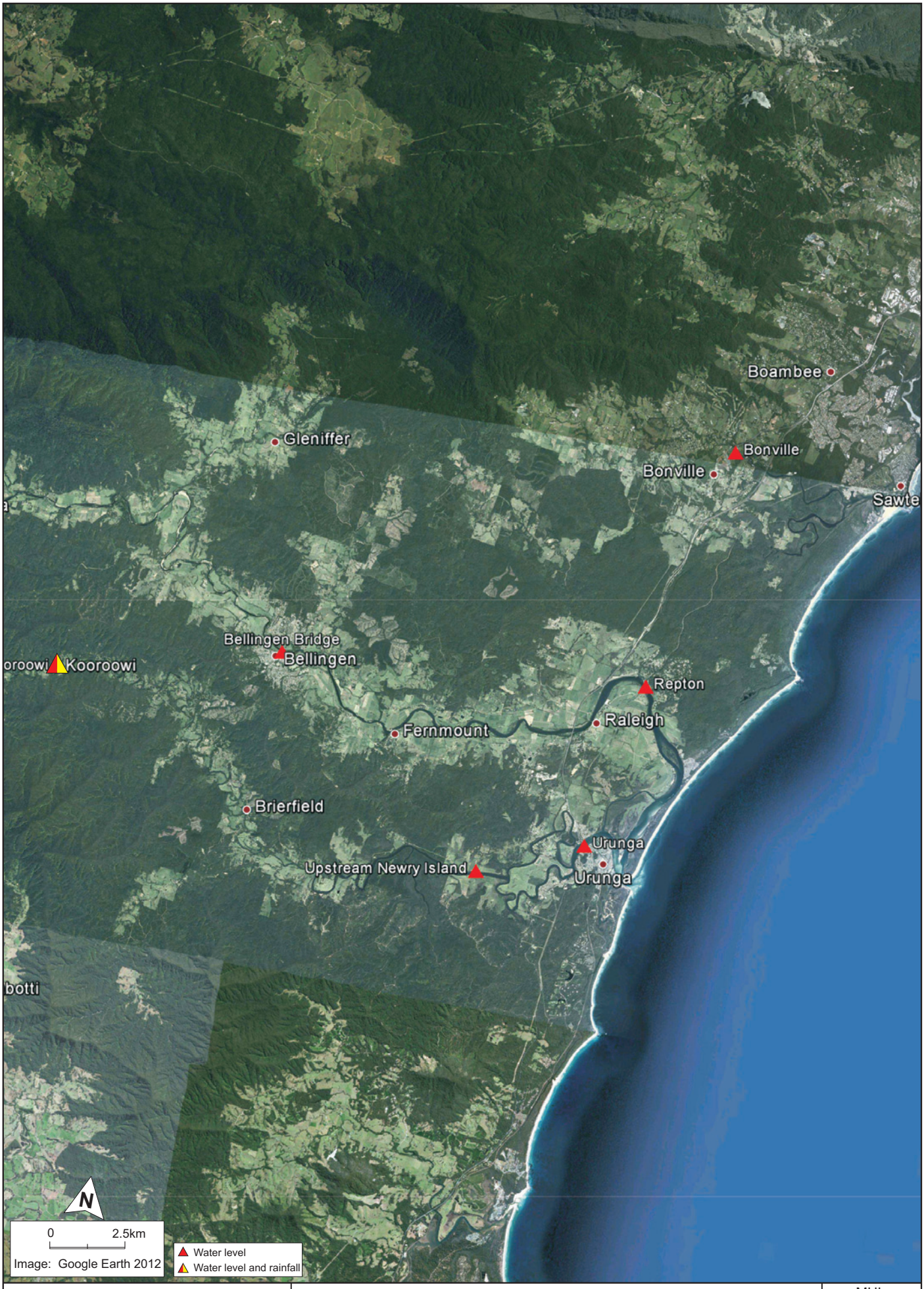
- No discernible flood hydrograph recorded at these stations
AHD Australian Height Datum

9.2 Bellinger River Region Rainfall

9.00 a.m. daily rainfall totals are displayed in Figure 9.2 and Table 9.3 for the period 24 January to 5 March 2013. The rainfall data and intensities are displayed graphically in Figure 9.3.

Table 9.3 Bellinger Region Daily Rainfall Totals

Date	Kooroowi (mm)
24/01/2013	48.0
25/01/2013	23.5
26/01/2013	3.5
27/01/2013	33.5
28/01/2013	169.0
29/01/2013	48.5
30/01/2013	0.0
31/01/2013	0.0
01/02/2013	0.0
02/02/2013	76.0
03/02/2013	0.0
04/02/2013	0.0
05/02/2013	1.5
06/02/2013	0.0
07/02/2013	0.5
08/02/2013	0.0
09/02/2013	0.0
10/02/2013	0.0
11/02/2013	0.0
12/02/2013	0.0
13/02/2013	41.5
14/02/2013	0.0
15/02/2013	5.0
16/02/2013	4.0
17/02/2013	29.0
18/02/2013	9.5
19/02/2013	8.0
20/02/2013	42.5
21/02/2013	42.5
22/02/2013	50.0
23/02/2013	194.5
24/02/2013	4.0
25/02/2013	21.0
26/02/2013	5.5
27/02/2013	1.5
28/02/2013	1.0
01/03/2013	0.0
02/03/2013	17.0
03/03/2013	65.0
04/03/2013	22.0
05/03/2013	9.0
Total	**976.5**



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STATION LOCATIONS
BELLINGER RIVER REGION

MHL Report 2202

Figure 9.1

DRAWING 2202-09-01.cdr

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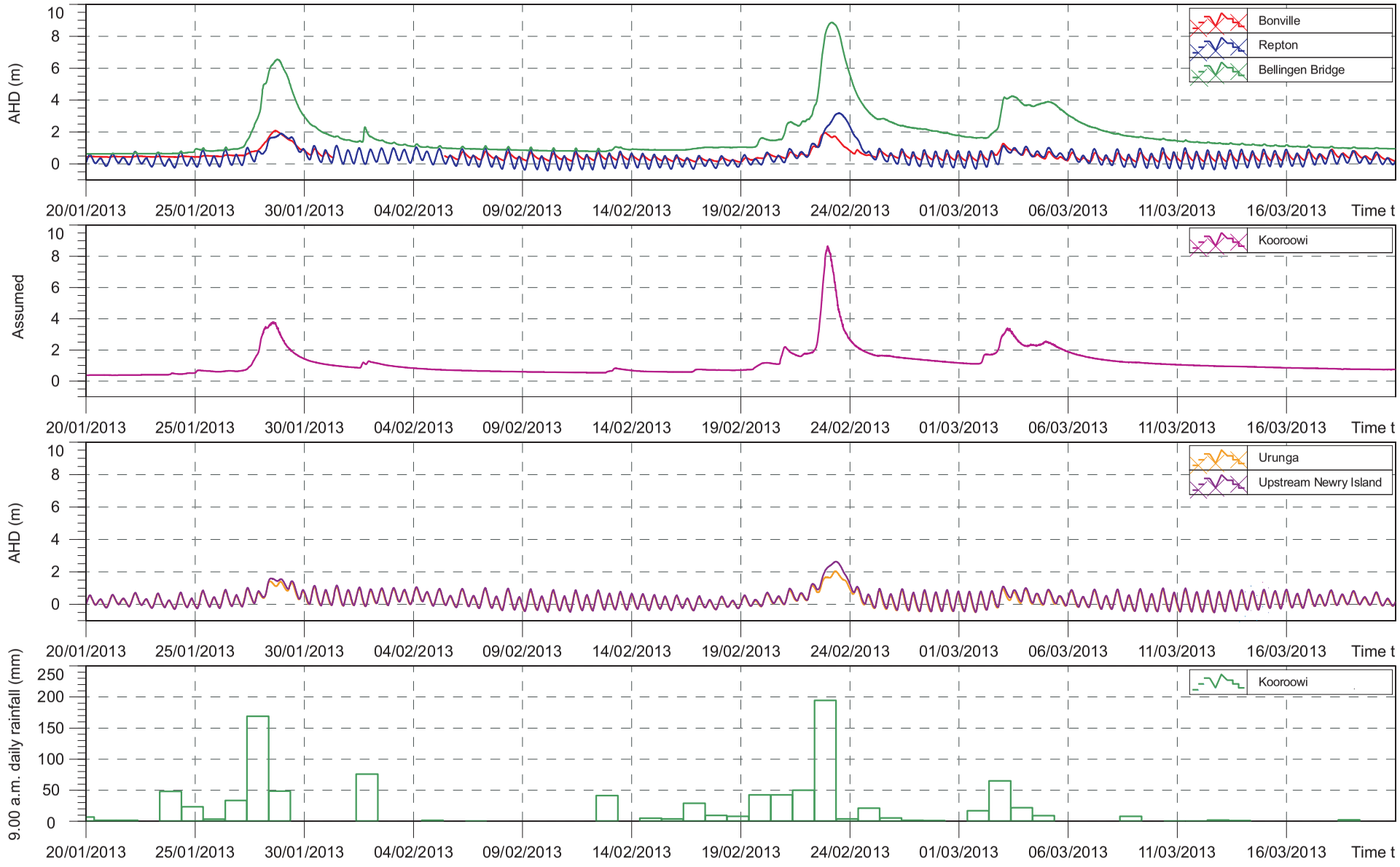
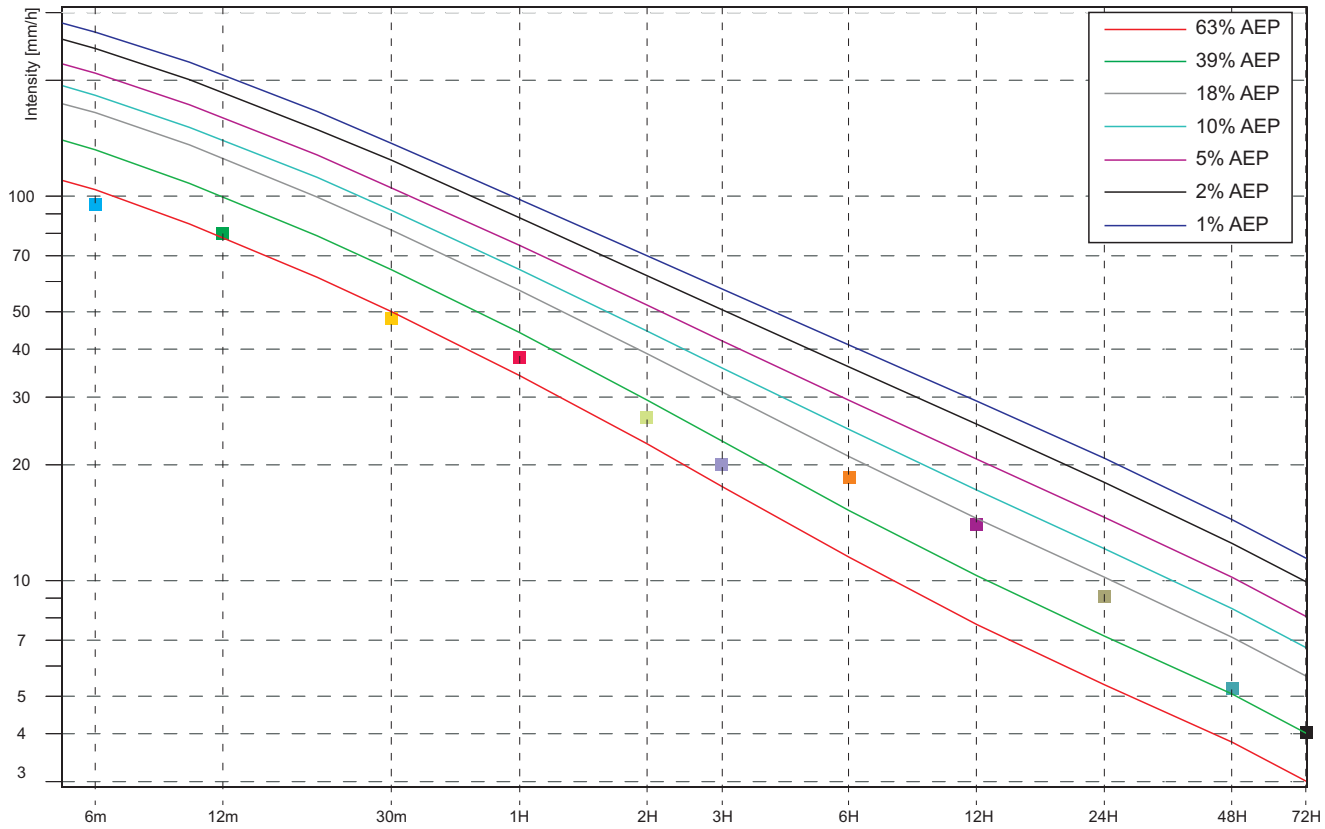
BELLINGER RIVER REGION
WATER LEVEL AND RAINFALL DATA
20 JANUARY-20 MARCH 2013



MHL Report 2202

Figure 9.2

DRAWING 2202-09-02.cdr



Duration
(minutes: m, hours: H)
Reference: Australian Rainfall and Runoff 1987

Kooroowi Rainfall Intensity 21 January-21 March 2013		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	95.00	1/02/2013 13:40
12m	80.00	1/02/2013 13:42
30m	48.00	1/02/2013 13:54
1H	38.00	1/02/2013 14:30
2H	26.50	1/02/2013 15:30
3H	20.00	1/02/2013 15:48
6H	18.50	22/02/2013 19:10
12H	13.96	22/02/2013 21:48
24H	9.10	22/02/2013 23:20
48H	5.25	22/02/2013 23:54
72H	4.02	23/02/2013 7:42

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:
Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

The use of the term 'Average Recurrence Interval' (ARI) can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of Annual Exceedance Probability (AEP). For example, 'a rainfall total of 60mm falling in 3 hours at Cudgera has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year' can be easier to understand than the equivalent statement of 'rainfall total of 60mm in 3 hours has an ARI of 100 years'.

Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml

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KOOROOWI
INTENSITY-FREQUENCY-DURATION
21 JANUARY-21 MARCH 2013

MHL Report 2202
Figure 9.3
DRAWING 2202-09-03.cdr

10. Nambucca River Region

10.1 Nambucca River Region Water Level

The locations of water level stations within the Nambucca River region are shown in Figure 10.1. The water level data for the period 20 January to 20 March 2013 can be viewed graphically in Figure 10.2. The peak water levels are listed in Table 10.1.

Table 10.2 lists the Bureau of Meteorology flood classification for Macksville. The BoM classification scheme indicates the flood peaks for Macksville were classified as below minor, moderate and below minor floods during the January, February and March floods, respectively.

Table 10.1 Nambucca River Region Flood Peaks

Station	Datum	Peak level (m)	Event 1 Time/Date	Peak level (m)	Event 2 Time/Date	Peak level (m)	Event 3 Time/Date
Deep Creek	AHD	1.34	0930 28/01/2013	1.77	2030 22/02/2013	1.05	0000 03/03/2013
Stuarts Island Downstream	AHD	1.27	0945 29/01/2013	1.85	0730 23/02/2013	1.02	0000 03/03/2013
Macksville	AHD	1.37	1015 29/01/2013	2.47	1145 23/02/2013	1.17	0045 03/03/2013
Bowraville Downstream	ASSU MED	2.10	1245 28/01/2013	5.57	0415 23/02/2013	2.95	0115 03/03/2013
Utungun	AHD	2.57	0530 29/01/2013	5.98	1430 23/02/2013	2.59	1400 03/03/2013
Warrell Creek	AHD	2.431	0415 29/01/2013	#	#	#	#

The AWLR at Warrell Creek failed to capture the February and March flood peaks (refer to Appendix A – Station Performance).

AHD Australian Height Datum

Table 10.2 BoM Flood Gauge Classification for Nambucca River Region

Station	Classification			Peak (m)	Classification
	Minor	Moderate	Major		
	Water Level AHD (m)				
Macksville	1.7	2.1	2.6	1.37 (29/01/2013)	Below Minor
				2.47 (23/02/2013)	Moderate
				1.17 (03/03/2013)	Below Minor

AHD Australian Height Datum

10.2 Nambucca River Region Rainfall

9.00 a.m. daily rainfall totals are displayed in Figure 10.2 and Table 10.3 for the period 24 January to 5 March 2013. The rainfall data and intensities are displayed graphically in Figures 10.3 and 10.4.

Table 10.3 Nambucca Region Daily Rainfall Totals

Date	Stuarts Island Downstream (mm)	Utungun (mm)
24/01/2013	11.5	20.0
25/01/2013	41.0	14.0
26/01/2013	2.5	3.0
27/01/2013	34.0	48.5
28/01/2013	73.5	121.0
29/01/2013	66.5	75.0
30/01/2013	0.0	0.0
31/01/2013	0.0	0.0
01/02/2013	0.0	0.0
02/02/2013	14.5	14.5
03/02/2013	0.5	0.0
04/02/2013	0.0	0.0
05/02/2013	0.0	1.5
06/02/2013	6.0	4.0
07/02/2013	0.5	1.5
08/02/2013	0.0	0.0
09/02/2013	0.0	0.0
10/02/2013	0.0	0.0
11/02/2013	0.0	0.0
12/02/2013	0.0	0.0
13/02/2013	8.5	23.0
14/02/2013	0.5	0.0
15/02/2013	9.5	10.5
16/02/2013	1.0	6.5
17/02/2013	12.0	9.5
18/02/2013	5.0	2.0
19/02/2013	11.5	6.0
20/02/2013	11.0	11.5
21/02/2013	23.0	44.5
22/02/2013	23.5	46.0
23/02/2013	88.5	189.5
24/02/2013	2.5	1.0
25/02/2013	14.0	22.5
26/02/2013	3.0	5.5
27/02/2013	0.0	2.5
28/02/2013	0.5	1.0
01/03/2013	0.0	0.5
02/03/2013	21.5	39.0
03/03/2013	35.5	73.0
04/03/2013	8.0	11.0
05/03/2013	1.0	6.5
Total	**530.5**	**814.5**

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STATION LOCATIONS
NAMBUCCA RIVER REGION

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Figure 10.1

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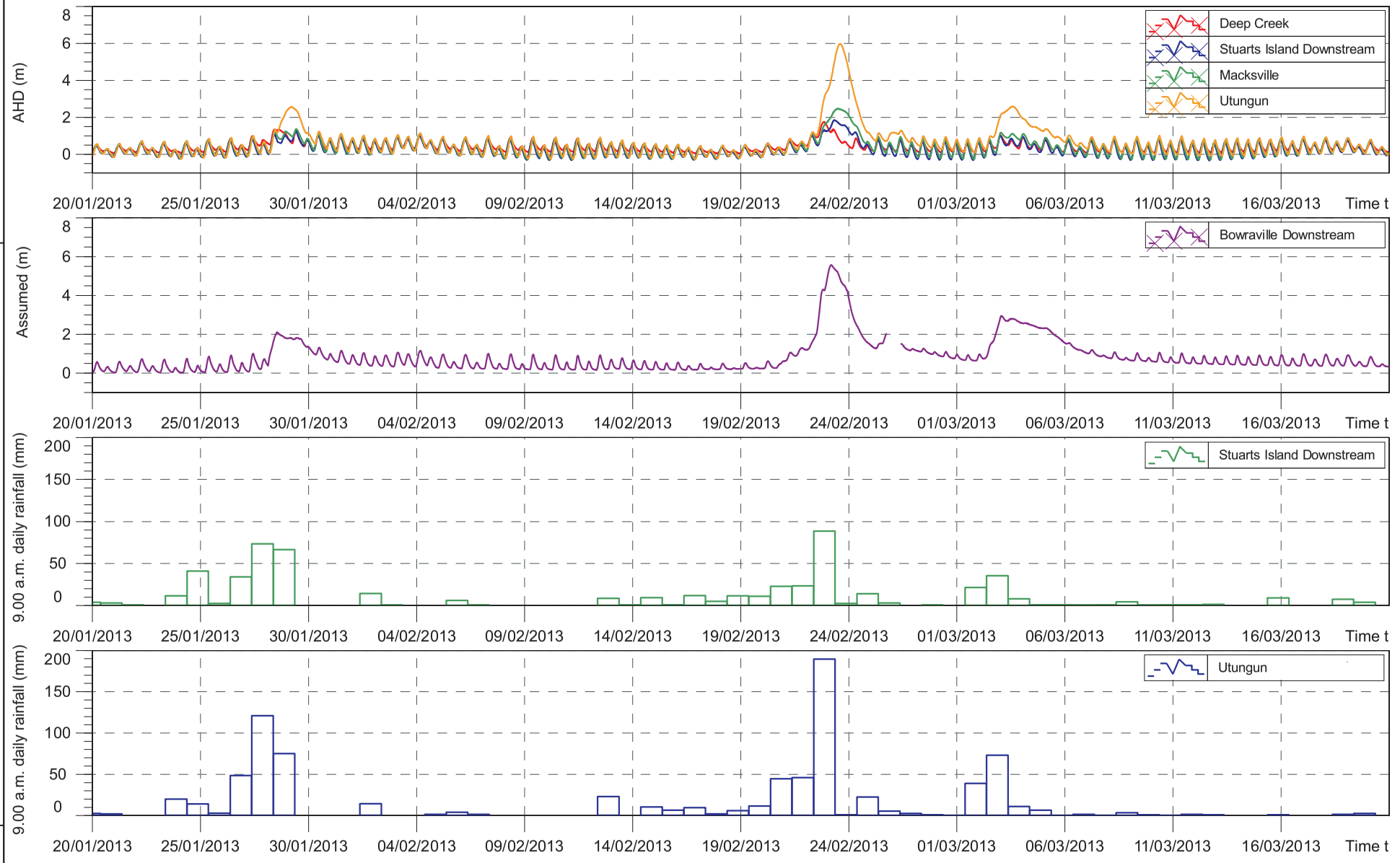
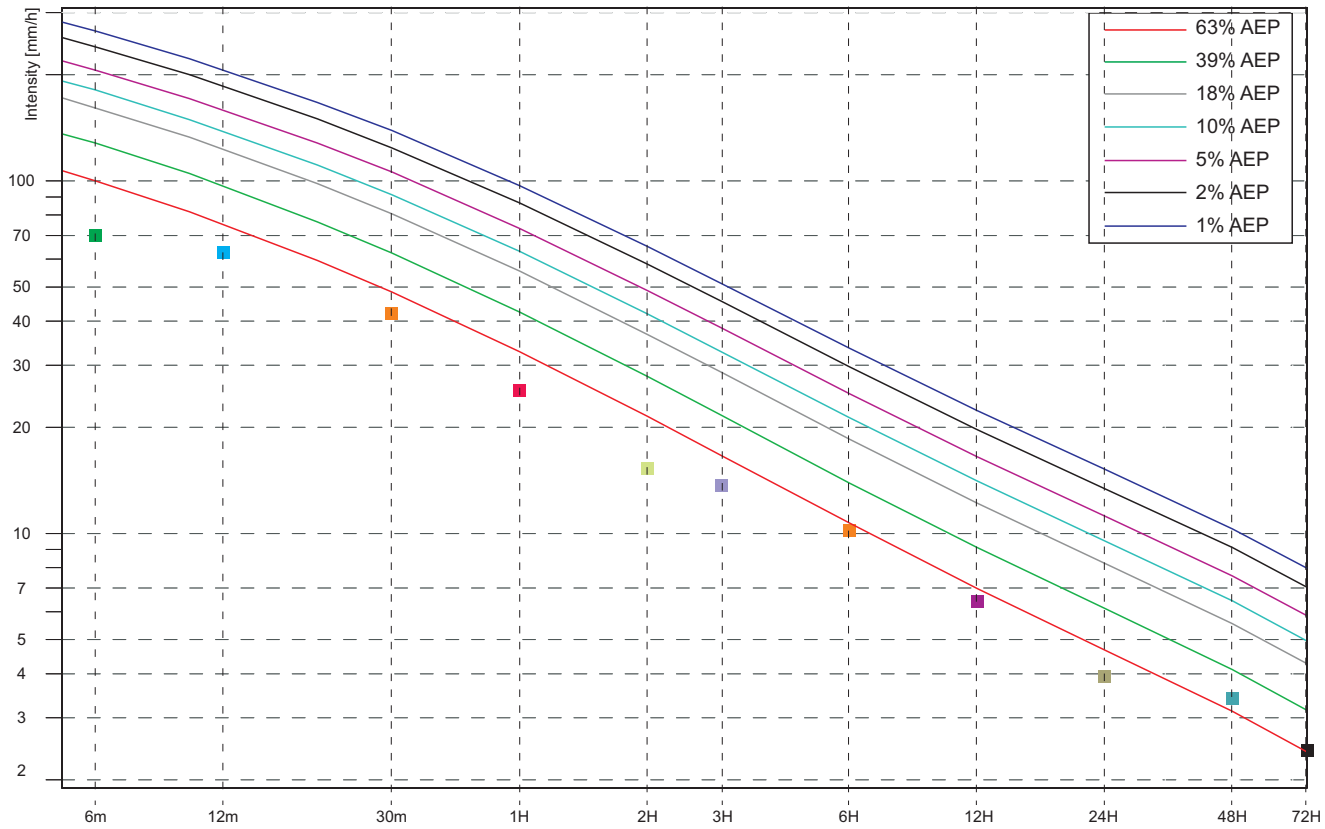
NAMBUCCA RIVER REGION
WATER LEVEL AND RAINFALL DATA
20 JANUARY-20 MARCH 2013



MHL Report 2202
Figure 10.2
DRAWING 2202-10-02.cdr



Duration
(minutes: m, hours: H)
Reference: Australian Rainfall and Runoff 1987

Stuarts Island Downstream Rainfall Intensity 21 January-21 March 2013		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	70.00	24/01/2013 23:06
12m	62.50	24/01/2013 23:12
30m	42.00	24/01/2013 23:24
1H	25.50	24/01/2013 23:52
2H	15.25	28/01/2013 11:54
3H	13.67	28/01/2013 12:54
6H	10.17	28/01/2013 13:00
12H	6.42	28/01/2013 14:14
24H	3.94	28/01/2013 14:14
48H	3.40	28/01/2013 18:20
72H	2.43	29/01/2013 7:40

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:
Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

The use of the term 'Average Recurrence Interval' (ARI) can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of Annual Exceedance Probability (AEP). For example, 'a rainfall total of 60mm falling in 3 hours at Cudgera has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year' can be easier to understand than the equivalent statement of 'rainfall total of 60mm in 3 hours has an ARI of 100 years'.

Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml

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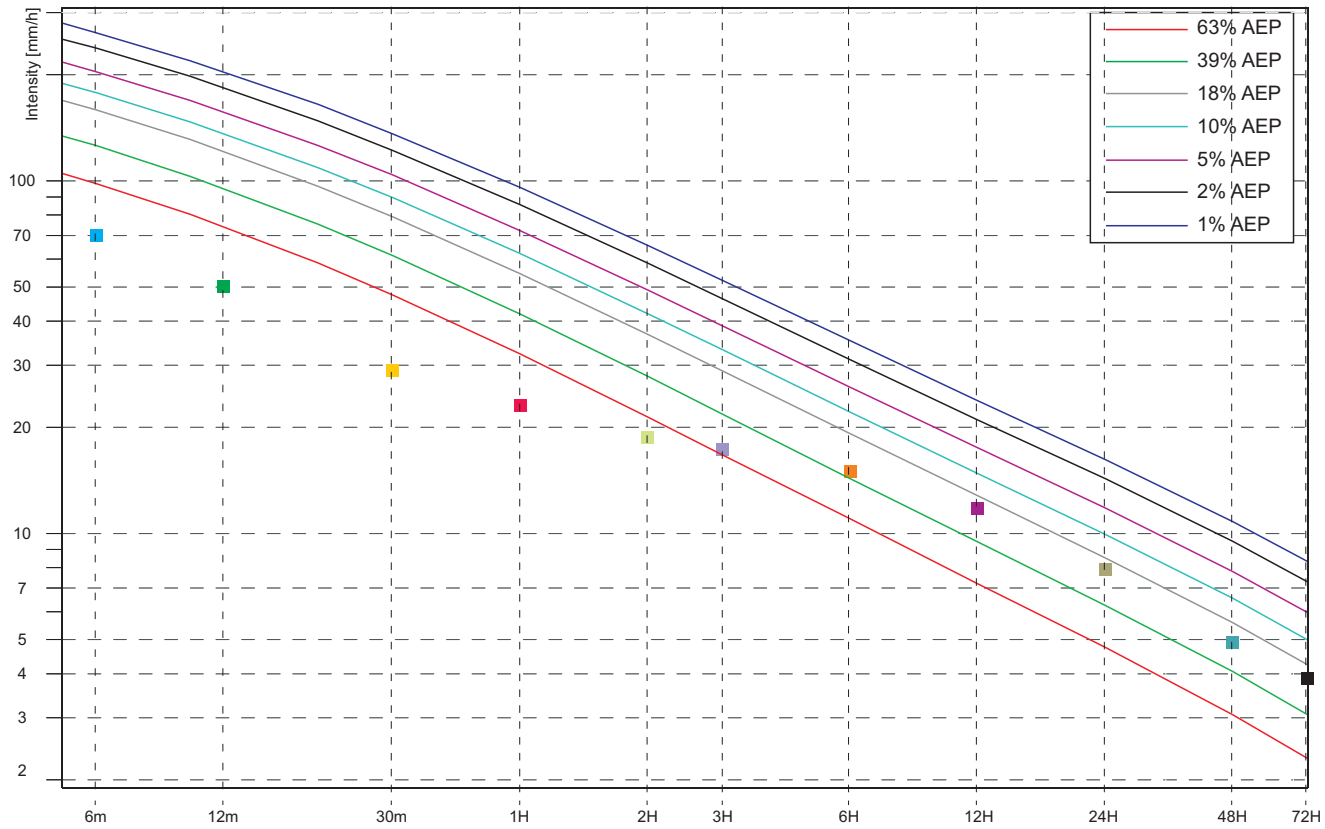
STUARTS ISLAND DOWNSTREAM
INTENSITY-FREQUENCY-DURATION
21 JANUARY-21 MARCH 2013

MHL Report 2202
Figure 10.3
DRAWING 2202-10-03.cdr



Duration
(minutes: m, hours: H)
Reference: Australian Rainfall and Runoff 1987

Utungun Rainfall Intensity 21 January-21 March 2013		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	70.00	26/01/2013 17:52
12m	50.00	1/02/2013 19:36
30m	29.00	22/02/2013 16:32
1H	23.00	22/02/2013 16:36
2H	18.75	22/02/2013 17:18
3H	17.33	22/02/2013 17:14
6H	15.00	22/02/2013 17:16
12H	11.80	22/02/2013 21:10
24H	7.90	23/02/2013 8:52
48H	4.92	23/02/2013 9:48
72H	3.90	23/02/2013 8:52

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:

Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

The use of the term 'Average Recurrence Interval' (ARI) can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of Annual Exceedance Probability (AEP). For example, 'a rainfall total of 60mm falling in 3 hours at Cudgera has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year' can be easier to understand than the equivalent statement of 'rainfall total of 60mm in 3 hours has an ARI of 100 years'.

Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml

11. Macleay River Region

11.1 Macleay River Water Level

The locations of water level stations within the Macleay River region are shown in Figure 11.1. The water level data for the period 20 January to 20 March 2013 can be viewed graphically in Figure 11.2. The peak water levels are listed in Table 11.1.

Table 11.2 lists the Bureau of Meteorology flood classification for Kempsey. The BoM classification scheme indicates the flood peaks at Kempsey were classified as below minor, major and moderate floods during the January, February and March floods, respectively.

Table 11.1 Macleay River Region Flood Peaks

Station	Datum	Peak level (m)	Event 1 Time/Date	Peak level (m)	Event 2 Time/Date	Peak level (m)	Event 3 Time/Date
Borirgala Creek	AHD	0.88	1800 29/01/2013	1.25	1645 23/02/2013	0.90	1215 03/03/2013
South West Rocks	AHD	1.26	0900 29/01/2013	1.18	0630 23/02/2013	0.98	0015 03/03/2013
Hat Head	AHD	1.21	0900 29/01/2013	1.11	0630 23/02/2013	-	-
Saltwater Lagoon	AHD	1.83	1700 28/01/2013	1.67	2115 22/02/2013	1.17	0030 03/03/2013
Smithtown	AHD	2.95	0000 30/01/2013	4.18	0530 24/02/2013	3.87	0400 04/03/2013
Kempsey	AHD	4.45	2115 29/01/2013	6.94	0445 24/02/2013	5.86	1800 03/03/2013
Aldavilla Downstream	AHD	5.33	1900 29/01/2013	9.65	0415 24/02/2013	6.96	1530 03/03/2013
Crescent Head	AHD	1.36	0915 29/01/2013	1.29	0645 23/02/2013	-	-

- No discernible flood hydrograph recorded at these stations
AHD Australian Height Datum

Table 11.2 BoM Flood Gauge Classification for Macleay River Region

Station	Classification			Peak (m)	Classification
	Minor	Moderate	Major		
	Water Level AHD (m)				
Kempsey	4.5	5.7	6.6	4.45 (29/01/2013)	Below Minor
				6.94 (24/02/2013)	Major
				5.86 (03/03/2013)	Moderate

AHD Australian Height Datum

11.2 Macleay River Region Rainfall

9.00 a.m. daily rainfall totals are displayed in Figure 11.2 and Table 11.3 for the period 24 January to 5 March 2013. The rainfall data and intensities for each event are displayed graphically in Figure 11.3.

Table 11.3 Macleay River Region Daily Rainfall Totals

Date	Aldavilla Downstream (mm)
24/01/2013	1.0
25/01/2013	14.0
26/01/2013	5.0
27/01/2013	31.0
28/01/2013	71.0
29/01/2013	90.0
30/01/2013	4.0
31/01/2013	0.0
01/02/2013	0.0
02/02/2013	34.0
03/02/2013	0.0
04/02/2013	0.0
05/02/2013	2.0
06/02/2013	0.0
07/02/2013	0.0
08/02/2013	0.0
09/02/2013	0.0
10/02/2013	0.0
11/02/2013	0.0
12/02/2013	0.0
13/02/2013	26.0
14/02/2013	0.0
15/02/2013	9.0
16/02/2013	3.0
17/02/2013	6.0
18/02/2013	4.0
19/02/2013	10.0
20/02/2013	*
21/02/2013	*
22/02/2013	*
23/02/2013	*
24/02/2013	*
25/02/2013	*
26/02/2013	*
27/02/2013	*
28/02/2013	*
01/03/2013	*
02/03/2013	*
03/03/2013	*
04/03/2013	*
05/03/2013	*
Total	**310.0**

*Bucket blocked 20 February to 6 March 2013

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STATION LOCATIONS
MACLEAY RIVER REGION

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Figure 11.1

DRAWING 2202-11-01.cdr

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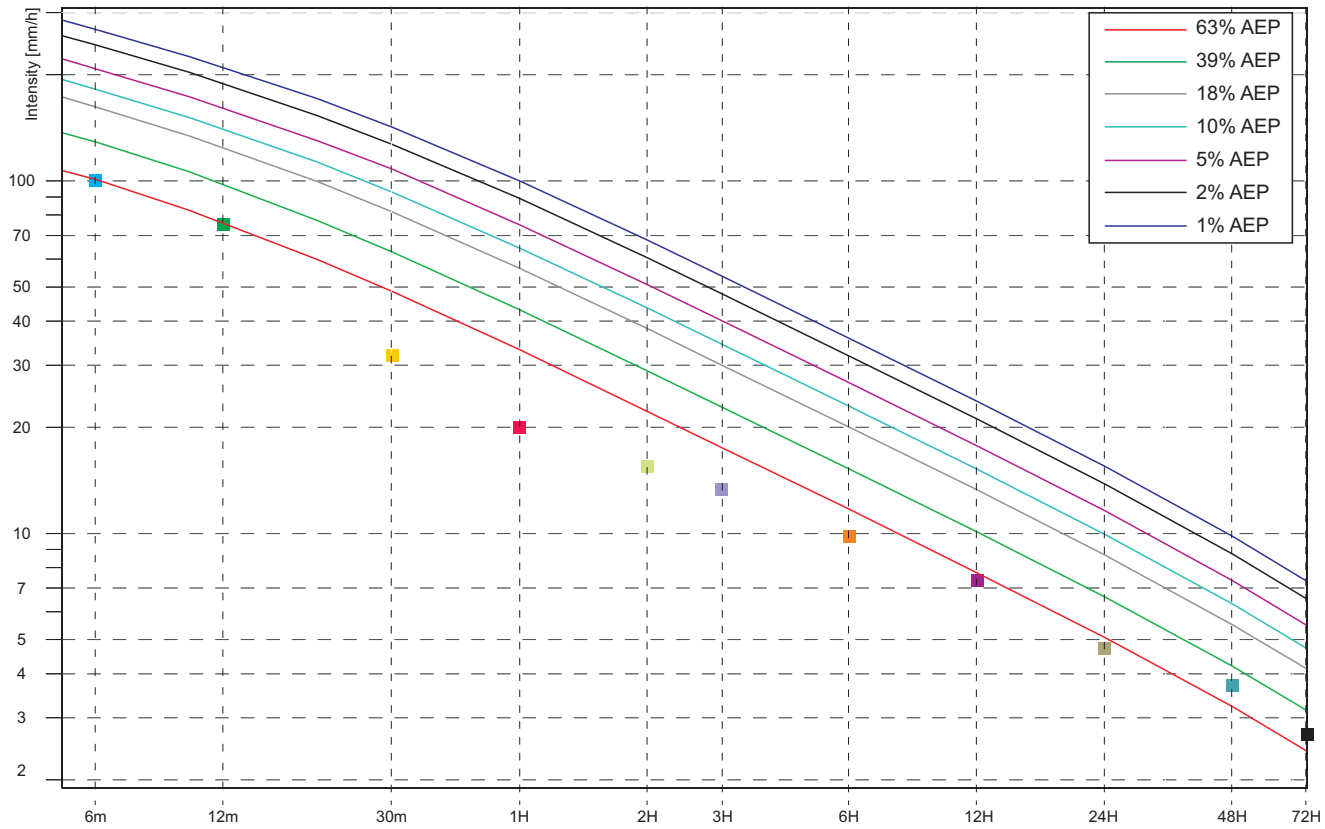
MACLEAY RIVER REGION
WATER LEVEL AND RAINFALL DATA
20 JANUARY-20 MARCH 2013

MHL Report 2202

Figure 11.2

DRAWING 2202-11-02.cdr



Duration
(minutes: m, hours: H)
Reference: Australian Rainfall and Runoff 1987

Aldavilla Downstream Rainfall Intensity 21 January-21 March 2013*		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	100.00	12/02/2013 17:36
12m	75.00	12/02/2013 17:42
30m	32.00	1/02/2013 19:46
1H	20.00	28/01/2013 13:28
2H	15.50	28/01/2013 13:36
3H	13.33	28/01/2013 14:22
6H	9.83	28/01/2013 16:04
12H	7.33	28/01/2013 18:42
24H	4.71	28/01/2013 19:16
48H	3.71	28/01/2013 21:22
72H	2.68	29/01/2013 15:48

*Data loss 20 February-6 March 2013

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:
Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

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Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml

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ALDAVILLA DOWNSTREAM
INTENSITY-FREQUENCY-DURATION
21 JANUARY-21 MARCH 2013

MHL Report 2202
Figure 11.3
DRAWING 2202-11-03.cdr

12. Hastings River Region

12.1 Hastings River Region Water Level

The locations of water level stations within the Hastings River region are shown in Figure 12.1. The water level data for the period 20 January to 20 March 2013 can be viewed graphically in Figure 12.2. The peak water levels are listed in Table 12.1.

Table 12.2 lists the Bureau of Meteorology flood classification for Wauchope Railway Bridge and Settlement Point. The BoM classification scheme indicates the flood peaks at Settlement Point were classified as below minor, moderate and below minor floods during the January, February and March floods, respectively.

Table 12.1 Hastings River Region Flood Peaks

Station	Datum	Peak level (m)	Event 1 Time/Date	Peak level (m)	Event 2 Time/Date	Peak level (m)	Event 3 Time/Date
Port Macquarie	AHD	1.11	0945 29/01/2013	1.36	0630 24/02/2013	0.97	0000 03/03/2013
Green Valley	AHD	1.72	1230 29/01/2013	2.42	2230 23/02/2013	1.70	0515 04/03/2013
Telegraph Point	AHD	1.92	0200 29/01/2013	2.64	1800 23/02/2013	1.78	0245 04/03/2013
Settlement Point	AHD	1.19	0930 29/01/2013	1.72	0645 24/02/2013	1.14	0145 04/03/2013
Dennis Bridge Downstream	AHD	1.27	1030 29/01/2013	2.77	2345 23/01/2013	1.72	0430 04/03/2013
Wauchope Railway Bridge	AHD	2.81*	0100 29/01/2013	7.22*	1915 23/02/2013	4.73*	0445 04/03/2013

* Flood peaks have been quality coded as poor, further investigation required.
AHD Australian Height Datum

Table 12.2 BoM Flood Gauge Classification for Hastings River Region

Station	Classification			Peak (m)	Classification
	Minor	Moderate	Major		
	Water Level AHD (m)				
Wauchope Railway Bridge	2.5	4.3	5.5	2.81* (29/01/2013)	Minor
				7.22* (23/02/2013)	Major
				4.73* (04/03/2013)	Moderate
Settlement Point	1.2	1.5	1.75	1.19 (29/01/2013)	Below Minor
				1.72 (24/02/2013)	Moderate
				1.14 (04/03/2013)	Below Minor

* Flood peaks have been quality coded as poor, further investigation required.
AHD Australian Height Datum

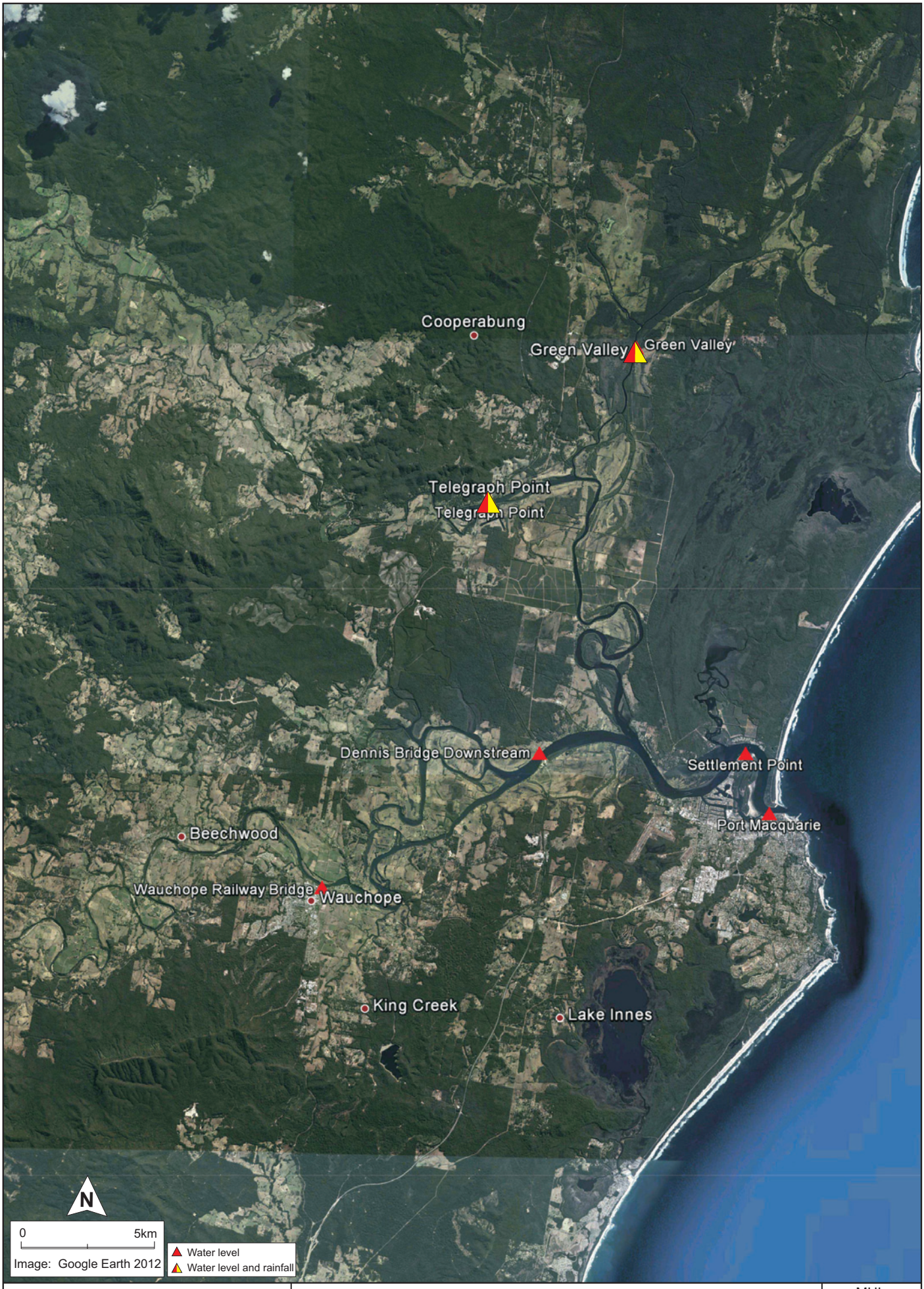
12.2 Hastings River Region Rainfall

9.00 a.m. daily rainfall totals are displayed in Figure 12.2 and Table 12.3 for the period 24 January to 5 March 2013. The rainfall data and intensities are displayed graphically in Figure 12.3.

Table 12.3 Hastings River Region Daily Rainfall Totals

Date	Green Valley (mm)	Telegraph Point (mm)
24/01/2013	3.0	0.0
25/01/2013	10.5	6.5
26/01/2013	19.0	15.0
27/01/2013	73.0	74.5
28/01/2013	95.5	106.5
29/01/2013	124.5	136.0
30/01/2013	3.0	7.0
31/01/2013	0.0	0.0
01/02/2013	0.0	0.0
02/02/2013	38.0	30.0
03/02/2013	0.0	0.0
04/02/2013	0.5	0.0
05/02/2013	6.5	6.5
06/02/2013	1.0	0.0
07/02/2013	3.0	3.5
08/02/2013	0.0	0.0
09/02/2013	0.0	0.0
10/02/2013	0.0	0.0
11/02/2013	0.0	0.0
12/02/2013	1.5	1.5
13/02/2013	21.0	17.5
14/02/2013	0.5	1.5
15/02/2013	9.0	3.0
16/02/2013	18.0	14.5

Date	Green Valley (mm)	Telegraph Point (mm)
17/02/2013	14.5	15.5
18/02/2013	22.5	30.5
19/02/2013	9.5	9.5
20/02/2013	2.0	7.0
21/02/2013	30.5	10.0
22/02/2013	43.0	38.5
23/02/2013	125.5	137.5
24/02/2013	90.0	89.0
25/02/2013	47.0	72.5
26/02/2013	4.5	12.0
27/02/2013	1.0	1.5
28/02/2013	2.5	3.5
01/03/2013	1.0	4.5
02/03/2013	0.5	23.5
03/03/2013	48.0	66.5
04/03/2013	6.5	14.5
05/03/2013	0.0	2.0
Total	**876.0**	**961.5**



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STATION LOCATIONS
HASTINGS RIVER REGION

MHL Report 2202

Figure 12.1

DRAWING 2202-12-01.cdr

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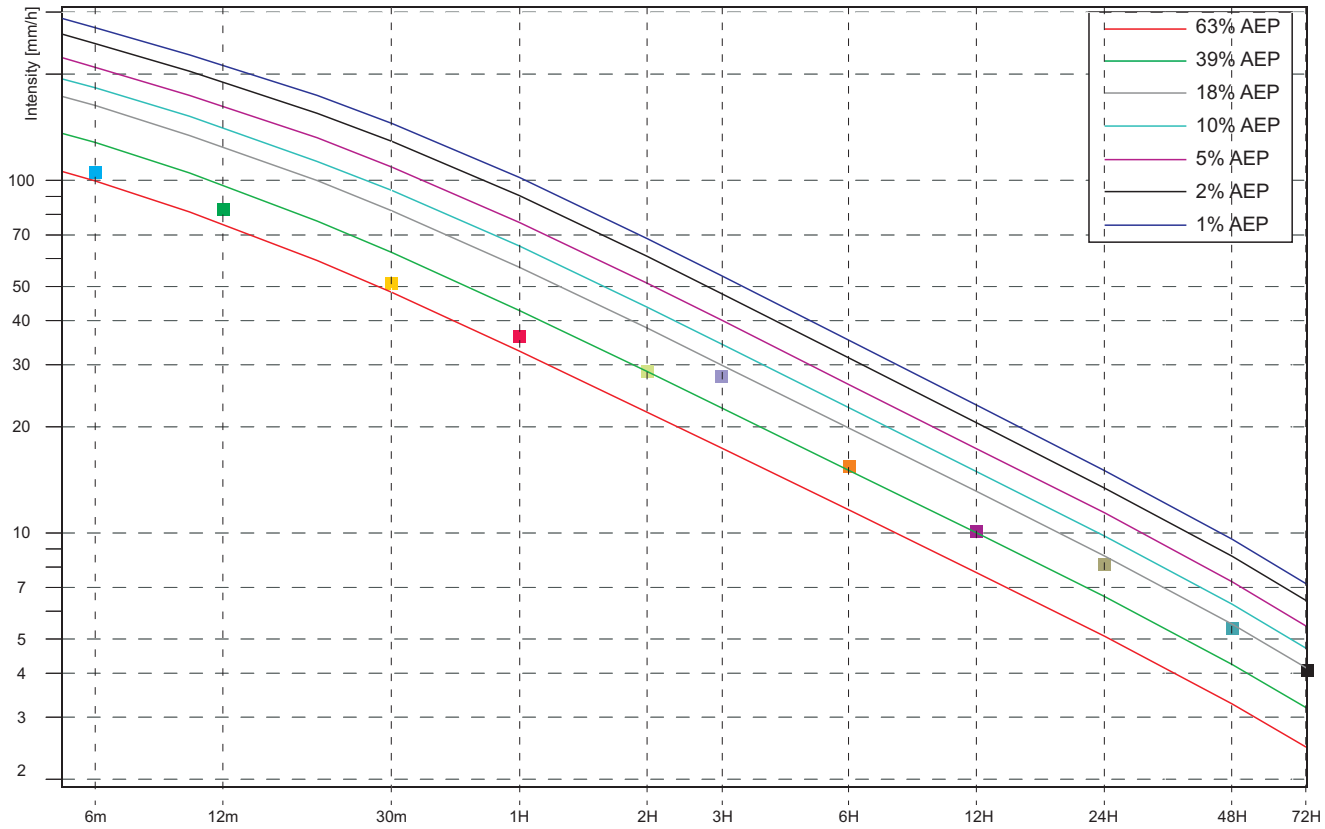
HASTINGS RIVER REGION
WATER LEVEL AND RAINFALL DATA
20 JANUARY-20 MARCH 2013

MHL Report 2202

Figure 12.2

DRAWING 2202-12-02.cdr



Duration
(minutes: m, hours: H)
Reference: Australian Rainfall and Runoff 1987

Green Valley Rainfall Intensity 21 January-21 March 2013		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	105.00	23/02/2013 9:34
12m	82.50	23/02/2013 9:38
30m	51.00	23/02/2013 9:46
1H	36.00	23/02/2013 11:50
2H	28.75	23/02/2013 12:24
3H	27.83	23/02/2013 12:20
6H	15.42	23/02/2013 12:24
12H	10.08	22/02/2013 19:18
24H	8.15	23/02/2013 12:24
48H	5.37	23/02/2013 16:00
72H	4.07	29/01/2013 8:44

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:
Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

The use of the term 'Average Recurrence Interval' (ARI) can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of Annual Exceedance Probability (AEP). For example, 'a rainfall total of 60mm falling in 3 hours at Cudgera has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year' can be easier to understand than the equivalent statement of 'rainfall total of 60mm in 3 hours has an ARI of 100 years'.

Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml

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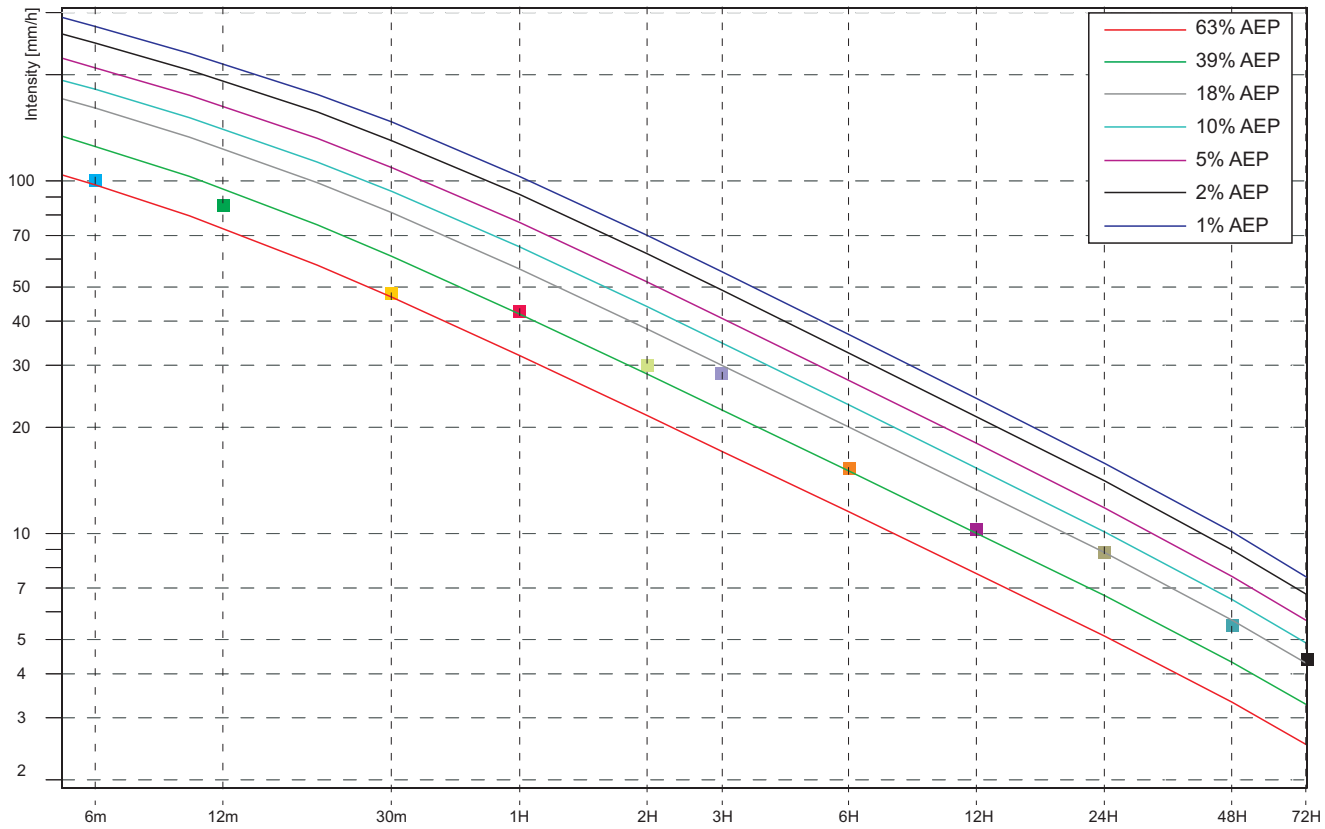
GREEN VALLEY
INTENSITY-FREQUENCY-DURATION
21 JANUARY-21 MARCH 2013

MHL Report 2202
Figure 12.3
DRAWING 2202-12-03.cdr



Duration
(minutes: m, hours: H)
Reference: Australian Rainfall and Runoff 1987

Telegraph Point Rainfall Intensity 21 January-21 March 2013		
Duration (minutes: m) (hours: H)	**Intensity (mm/hr)**	**Date/Time**
6m	100.00	17/02/2013 14:56
12m	85.00	23/02/2013 9:46
30m	48.00	23/02/2013 9:56
1H	42.50	23/02/2013 12:08
2H	30.00	23/02/2013 12:28
3H	28.50	23/02/2013 12:28
6H	15.25	23/02/2013 12:28
12H	10.29	22/02/2013 20:14
24H	8.81	23/02/2013 12:28
48H	5.49	28/01/2013 22:58
72H	4.40	29/01/2013 8:44

Australian Rainfall and Runoff (Institute of Engineers Australia 1987) states:
Use of the terms 'recurrence interval' and 'return period' has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance.

The use of the term 'Average Recurrence Interval' (ARI) can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of Annual Exceedance Probability (AEP). For example, 'a rainfall total of 60mm falling in 3 hours at Cudgera has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year' can be easier to understand than the equivalent statement of 'rainfall total of 60mm in 3 hours has an ARI of 100 years'.

Adapted from: http://www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml

Appendix A

Station Performance

Table A1 Station Performance

Station Name	Station Type	Jan-Mar Data Capture (%)	Explanation for Lost Data
Tweed River Region			
Tweed Heads	Ocean Tide	100	
Cobaki	Water Level	100	
Letitia 2A	Water Level	100	
Dry Dock	Water Level	100	
Terranora	Water Level	100	
Barneys Point	Water Level	100	
Tumbulgum	Water Level	100	
Kynnumboon	Water Level	100	
North Murwillumbah	Water Level	100	
Murwillumbah Bridge	Water Level	100	
Bray Park Weir	Water Level	100	
Kingscliff	Water Level	-	Siltation issues at site (data not included in this report). MHL is currently investigating another possible relocation
Bogangar	Water Level	100	
Brunswick River Region			
Billinudgel	Water Level	92	Power issue
Orana Bridge	Water Level	100	
Brunswick Heads	Ocean Tide	100	
Mullumbimby	Water Level	100	
Cudgera	Rainfall	100	
Main Arm	Rainfall	100	
Myocum	Rainfall	100	
Huonbrook	Rainfall	100	
Richmond River Region			
Lake Ainsworth	Rainfall	85	Blocked bucket
Lake Ainsworth	Water Level	100	
Ballina	Ocean Tide	100	
Missingham Bridge	Water Level	100	
Byrnes Point	Water Level	100	
Wardell	Water Level	100	
Woodburn	Water Level	100	
Bungawalbin	Water Level	100	
Coraki	Water Level	81	Gas line failure
East Gundurimba	Water Level	100	
Tuncester	Water Level	100	
Woodlawn College	Water Level	100	
Tucombil Highway Bridge	Water Level	95	Instrumentation failure
Tucombil Floodgate	Water Level	100	
Rocky Mouth Creek	Water Level	100	

Station Name	Station Type	Jan-Mar Data Capture (%)	Explanation for Lost Data
Evans River Fishing Co-op	Water Level	100	
Iron Gates	Water Level	100	
Clarence River			
Yamba	Ocean Tide	100	
Oyster Channel	Water Level	100	
Palmers Island Bridge	Water Level	100	
Maclean	Water Level	100	
Lake Wooloweyah	Water Level	100	
Lawrence	Water Level	99	Instrumentation failure
Tyndale	Water Level	100	
Brushgrove	Water Level	100	
Rogans Bridge	Water Level	100	
Ulmarra	Water Level	100	
Grafton	Water Level	100	
The Avenue Upstream	Water Level	100	
The Avenue Downstream	Water Level	100	
Coffs Harbour Region			
Wooli Caravan Park	Water Level	100	
Wooli Entrance	Water Level	100	
Red Rock	Water Level	100	
Woolgoolga Lake	Water Level	100	
Woolgoolga	Water Level	100	
Moonee Creek	Water Level	100	
Wooli Caravan Park	Rainfall	100	
Perry Drive	Rainfall	100	
Shepards Lane	Rainfall	100	
Red Hill	Rainfall	100	
Middle Boambee	Rainfall	100	
South Boambee	Rainfall	-	Data coded poor due to over shadowing of foliage (data not included in this report)
North Bonville	Rainfall	100	
Coffs Harbour	Ocean Tide	100	
Coffs Creek Highway Bridge	Water Level	100	
Newports Creek	Water Level	100	
Boambee	Water Level	100	
Boambee Entrance	Water Level	100	
Newports Creek	Rainfall	100	
Bellinger River Region			
Bonville	Water Level	100	
Repton	Water Level	100	
Bellingen Bridge	Water Level	100	
Urunga	Water Level	100	

Station Name	Station Type	Jan-Mar Data Capture (%)	Explanation for Lost Data
Upstream Newry Island	Water Level	100	
Kooroowi	Water Level	100	
Kooroowi	Rainfall	100	
Deep Creek	Water Level	100	
Stuarts Island Downstream	Water Level	100	
Macksville	Water Level	100	
Utungun	Water Level	100	
Bowraville Downstream	Water Level	99.5	
Warrell Creek	Water Level	-	Instrumentation failures (data not included in this report)
Stuarts Island Downstream	Rainfall	100	
Utungun	Rainfall	100	
Macleay River Region			
South West Rocks	Water Level	100	
Smithtown	Water Level	100	
Kempsey	Water Level	100	
Aldavilla Downstream	Water Level	100	
Aldavilla Downstream	Rainfall	78	Blocked bucket
Borirgala Creek	Water Level	100	
Saltwater Lagoon	Water Level	100	
Hat Head	Water Level	100	
Crescent Head	Water Level	100	
Hastings River			
Port Macquarie	Ocean Tide	100	
Settlement Point	Water Level	100	
Dennis Bridge Downstream	Water Level	100	
Wauchope Railway Bridge	Water Level	91	Gas leak
Telegraph Point	Water Level	100	
Green Valley	Water Level	100	
Telegraph Point	Rainfall	100	
Green Valley	Rainfall	100	

Appendix B

Flood Photographs

January 2013 Event

Woodlawn College, Wilson River, 7.10 am, 27 January 2013

Coraki, Richmond River, 3.20 pm, 28 January 2013

Lismore Bridge, Wilsons River, 8.40 am, 27 January 2013

Rogans Bridge, Clarence River (post-flood), 11.20 am, 2 February 2013

Grafton, Clarence River, 8.00 am, 29 January 2013

Grafton Flood Height Indicator, Clarence River, 7.50 am, 29 January 2013

Grafton Levee, Clarence River, 8.50 am, 29 January 2013

Grafton Bowling Club, Clarence River, 9.40 am, 29 January 2013

February 2013 Event

View from Kempsey Bridge, Macleay River, 7.40 am, 23 February 2013

Kempsey levee, Macleay River, 7.55 am, 23 February 2013

Kempsey bus stop, Macleay River, 8.00 am, 23 February 2013

Corner Smithtown Road and Pacific Highway, Bellimbopinni, 10.00 am, 23 February 2013

Pacific Highway (between Bellimbopinni and Macksville), 10.30 am, 23 February 2013

Macksville, 11.00 am, 23 February 2013

Appendix C

Adjustment to AHD

Table C1 Adjustment to AHD

River/Estuary	Station	Station Datum	Adjustment to AHD
Cobaki Broadwater	Cobaki	TRHD	-0.863
Terranora Creek	Dry Dock	TRHD	-0.875
Terranora Broadwater	Terranora	TRHD	-0.853
Tweed River	Tweed Heads	TRHD	-0.893
Tweed River	Letitia 2A	TRHD	-0.886
Tweed River	Barneys Point	TRHD	-0.883
Tweed River	Tumbulgum	TRHD	-0.893
Tweed River	North Murwillumbah	TRHD	-0.909
Tweed River	Murwillumbah Bridge	TRHD	-0.909
Rous River	Kynnumboon	TRHD	-0.926
Brunswick River	Brunswick Heads	BRFMD	-0.046
Cudgen Creek	Kingscliff	BRFMD	-0.066
Marshalls Creek	Orana Bridge	BRFMD	-0.024
Marshalls Creek	Billinudgel	BRFMD	-0.019
Brunswick River	Mullumbimby	BRFMD	-0.010
Richmond River	Ballina	LWOST	-0.860
Richmond River	Missingham Bridge	RRVD	-0.860
Richmond River	Byrnes Point	RRVD	-0.857
Richmond River	Wardell	RRVD	-0.824
Richmond River	Woodburn	RRVD	-0.815
Evans River	Evans River Fishing Co-op	RRVD	-0.809
Evans River	Iron Gates	RRVD	-0.819
Tucombil Canal	Tucombil Highway Bridge	RRVD	-0.815
Tucombil Canal	Tucombil Floodgate	RRVD	-0.815
Rocky Mouth Creek	Rocky Mouth Creek	RRVD	-0.815
Richmond River	Bungawalbin	RRVD	-0.809
Richmond River	Coraki	RRVD	-0.815
Wilsons River	East Gundurimba	RRVD	-0.831
Leycester Creek	Tuncester	RRVD	-0.855
Wilsons River	Woodlawn College	RRVD	-0.826
Wilsons River	Lismore Rowing Club^	RRVD	-0.860

^ Lismore City Council station

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