Manly Hydraulics Laboratory

NSW WAVE CLIMATE AND COASTAL AIR PRESSURE ANNUAL SUMMARY 2016–2017

Report MHL2576
November 2017

Prepared for:

Office of Environment and Heritage

Department of Finance, Services & Innovation

Cover Photograph: Batemans Bay Waverider buoy, 14 October 2015

NSW WAVE CLIMATE AND COASTAL AIR PRESSURE ANNUAL SUMMARY 2016–2017

Report MHL2576
November 2017

Mark Kulmar
110b King Street
Manly Vale NSW 2093
T: 02 9949 0200
E: mark.kulmar@mhl.nsw.gov.au
W: www.mhl.nsw.gov.au

Document Control

Issue/ Revision	Author	Reviewer	Approved for Issue	
			Name	Date
Draft	M Kulmar, MHL	S Maddox, MHL M Fitzhenry, OEH		
Final	M Kulmar, MHL		E Couriel	28/11/2017

Report No. MHL2576
ISSN 2205-5584 (Print)
ISSN 2205-5592 (Online)
First published November 2017

Manly Hydraulics Laboratory is Quality System Certified to AS/NZS ISO 9001:2008.

Foreword

This annual summary presents the ocean wave climate and air pressure information collected along the New South Wales coast from 1 July 2016 to 30 June 2017. Wave and air pressure data are collected for the NSW Office of Environment and Heritage by Manly Hydraulics Laboratory. Previous annual summaries have documented the available wave data for each offshore wave data station and air pressure data from the digital barometer network from the start of records.

Wave and air pressure data are being collected to provide essential input into design, construction and performance monitoring of projects undertaken as part of the NSW Government programs in the areas of coastal management, beach improvement, estuary management, ports and marine facilities, waterways and fishing, and wastewater engineering.

The summary has been prepared to catalogue available wave and air pressure data and provide information on the analysis/presentation software resident at Manly Hydraulics Laboratory.

Requests for further information should be directed to:

Manly Hydraulics Laboratory
110b King Street
Manly Vale NSW 2093
Attention: Mr Mark Kulmar

Telephone : (02) 9949 0200
e-mail : mark.kulmar@mhl.nsw.gov.au
WWW : www.mhl.nsw.gov.au

Other annual summaries in this series include:

- NSW Estuary and River Water Levels
  Annual Summary 2016–2017
  Many Hydraulics Laboratory
  Report No. MHL2573
  ISSN: 2205-5525 (Print)
  ISSN: 2205-5533 (Online)
- NSW Coastal Rainfall
  Annual Summary 2016–2017
  Manly Hydraulics Laboratory
  Report No. MHL2575
  ISSN: 2205-5568 (Print)
  ISSN: 2205-5576 (Online)
- NSW Ocean and River Entrance Tidal Levels
  Annual Summary 2016–2017
  Manly Hydraulics Laboratory
  Report No. MHL2574
  ISSN: 2205-5541 (Print)
  ISSN: 2205-555X (Online)
- NSW Estuary and River Water Quality
  Annual Summary 2016–2017
  Manly Hydraulics Laboratory
  Report No. MHL2577
  ISSN: 2205-5606 (Print)
  ISSN: 2205-5614 (Online)

Electronic copies of the reports in this series can be downloaded at www.mhl.nsw.gov.au under the ‘Publications’ menu.

Contents

APPENDICES

TABLES

FIGURES

1. Wave climate program

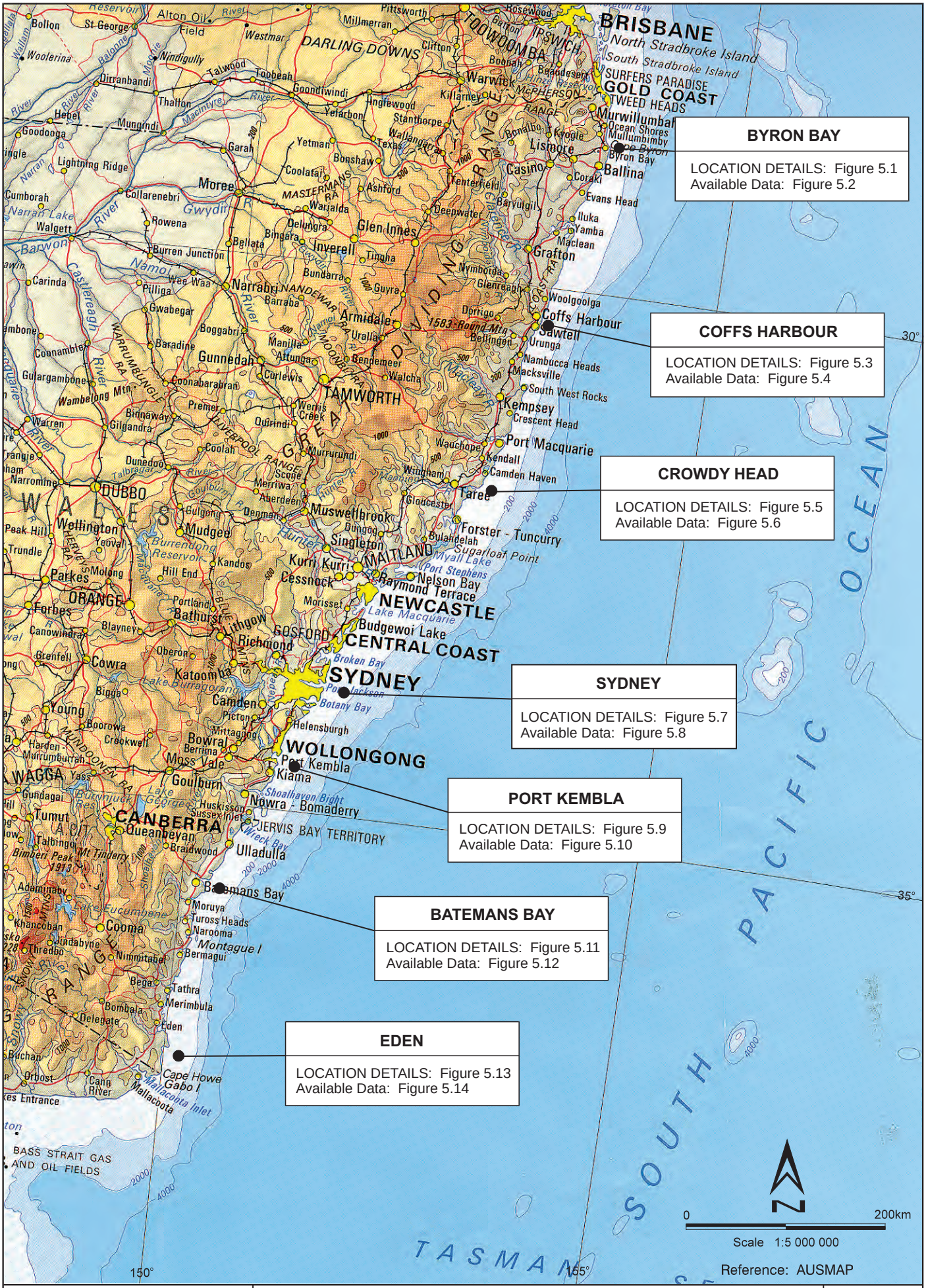
The NSW Wave Climate Program is centred around a network of offshore wave sensing buoys (Figure 1.1) which telemeter information to onshore recording stations. All stations are based on the Datawell Waverider system which uses an accelerometer mounted in a loose-tethered buoy to measure the vertical accelerations of the buoy as it moves with the water surface. The accelerations are integrated twice within the buoy and the displacement signal so obtained is then transmitted to the shore station. In recent years, buoys that also measure wave direction have replaced the original non-directional buoys. The Directional Waverider buoy was also developed by Datawell and utilises three accelerometers and a compass to provide wave direction information. At the receiving station the Waverider data signal is processed and stored by a personal computer (PC) and telemetered every hour via the internet to Manly Hydraulics Laboratory's central server.

Routine offshore wave measurement commenced in 1971 with the establishment of a Sydney station by the Maritime Services Board off Botany Bay. This was followed in 1974 by the then Public Works Department's first station at Port Kembla. Following the establishment of the Port Kembla station, coastal studies by the Public Works Department required further Waverider buoys to be deployed to monitor site specific wave conditions. During these early deployments the importance of reliable long-term wave statistics for coastal management and design purposes was emphasised by several destructive storms that caused severe beach erosion and considerable damage to coastal structures. As a result, during the 1980s the operation of the Waverider buoys was continued to establish a database of offshore wave statistics for the NSW coast.

In March 1992 the Waverider buoy network was enhanced through the deployment of a Directional Waverider buoy off Sydney. As the name suggests, the Directional Waverider buoy measures wave direction in addition to wave height and period. Following the success of the Sydney Directional Waverider buoy deployment, a second Directional Waverider buoy was added to the network in October 1999 when the Byron Bay station was upgraded to a directional site. To provide directional data for the NSW south coast region, the Batemans Bay Waverider station was also upgraded with a Directional Waverider buoy in February 2001. During 2011 and 2012 the buoys at Coffs Harbour, Crowdy Head, Port Kembla and Eden were all upgraded with Directional Waverider buoys, thus enabling the measurement of wave direction at all NSW offshore wave monitoring stations. The Directional Waverider buoys also measure sea surface temperature that is telemetered to the receiving station along with the wave data.

Figure 1.2 presents a flowchart of the wave data collection, distribution and presentation system operated by Manly Hydraulics Laboratory.

Detailed station location information and data plots for 2016–2017 for all offshore sites are presented in Figures 5.1 to 5.14.



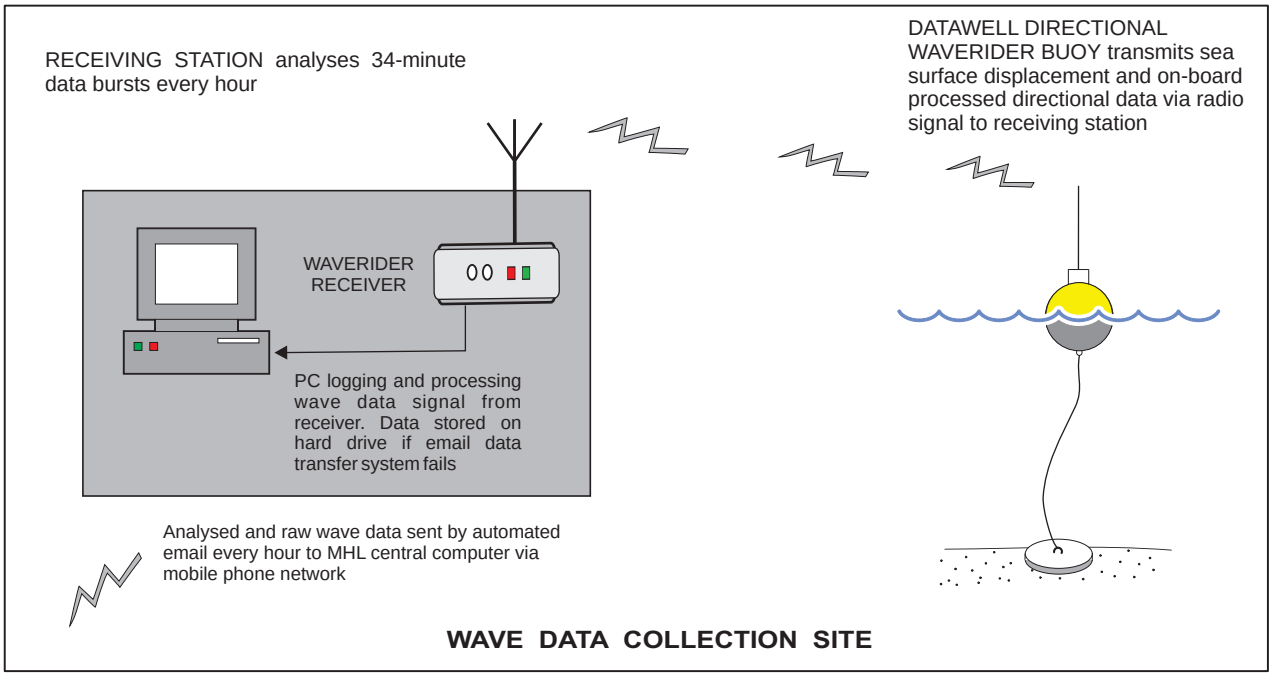
NSW GOVERNMENT Manly Hydraulics Laboratory

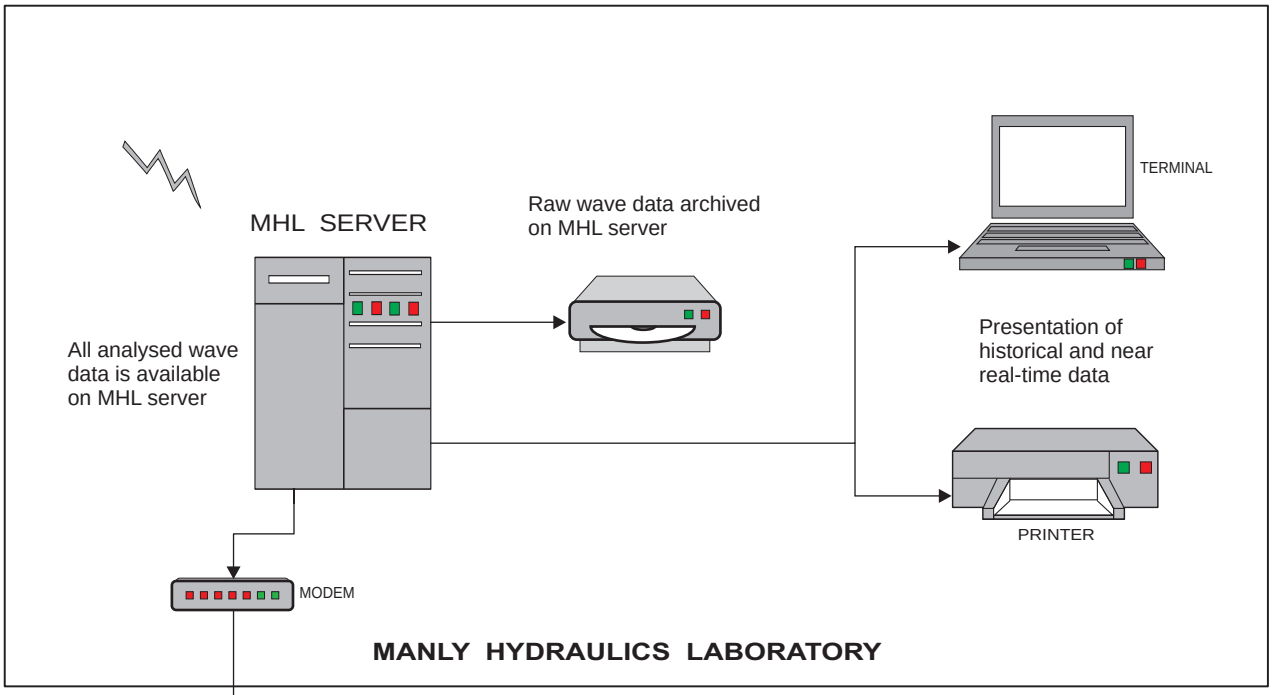
NEW SOUTH WALES OFFSHORE DIRECTIONAL WAVERIDER BUOY LOCATIONS

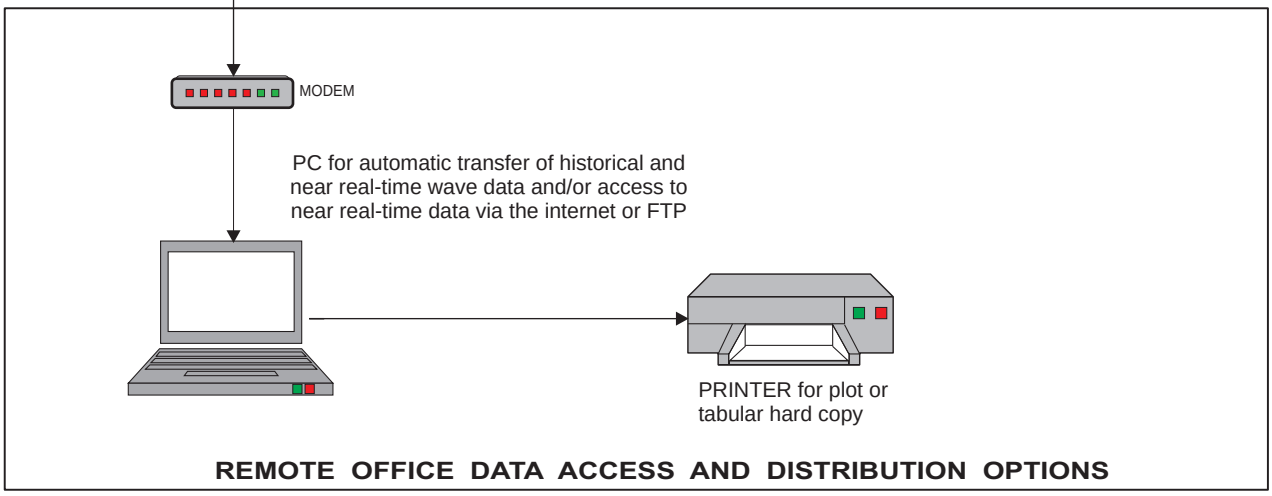
MHL Report 2576

Figure 1.1

DRAWING 2576-01-01.cdr







NSW GOVERNMENT Manly Hydraulics Laboratory

WAVE DATA COLLECTION, DISTRIBUTION AND PRESENTATION SYSTEM

MHL Report 2576

Figure 1.2

DRAWING 2576-01-02.cdr

2. Air pressure program

Manly Hydraulics Laboratory has measured air pressure along the NSW coast since 1987. Barometers developed by Manly Hydraulics Laboratory, utilising a SPX100 pressure transducer, were installed at six Waverider buoy receiving stations until the network was decommissioned during late 1999. The original SPX100 barometer network was superseded by a more comprehensive coastal air pressure monitoring system between August 1999 and February 2000 (Figure 2.1). This data is recorded to allow the correction of water level data recorded by total pressure transducers and to provide barometric information to assist understanding of water levels associated with ocean storms.

The barometer network utilises Vaisala digital barometers that sample air pressure every 15 minutes to an accuracy of ± 0.2 hPa. At the barometer station air pressure data is corrected to mean sea level and stored by a Campbell CR800 data logger before it is downloaded twice per day to Manly Hydraulics Laboratory's central computer by telephone link.

Figure 2.2 presents a flowchart of the air pressure data collection, distribution and presentation system operated by Manly Hydraulics Laboratory.

Manly Hydraulics Laboratory

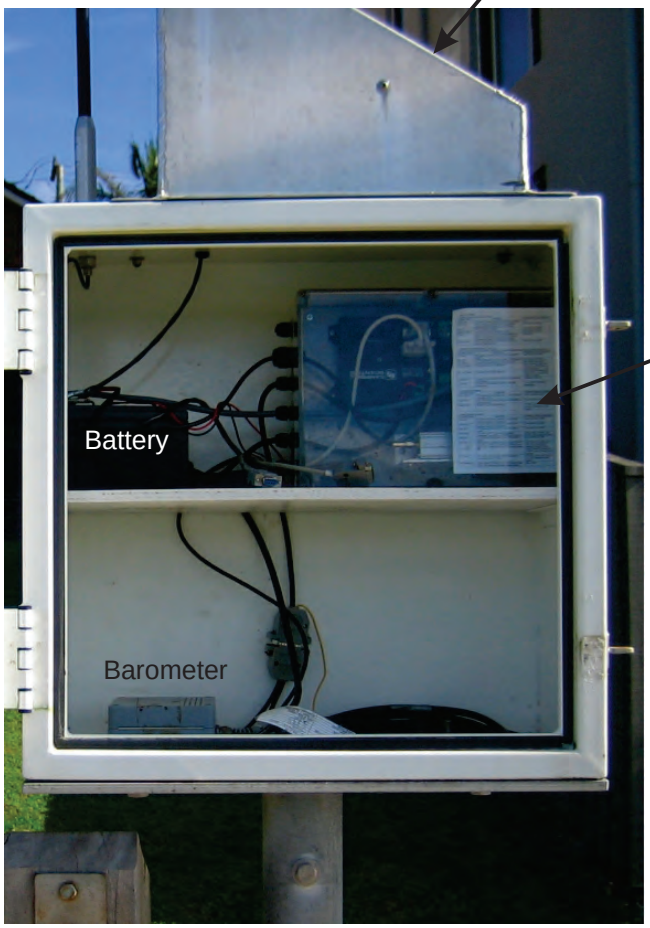
NSW GOVERNMENT

NEW SOUTH WALES COASTAL BAROMETER LOCATIONS

MHL Report 2576

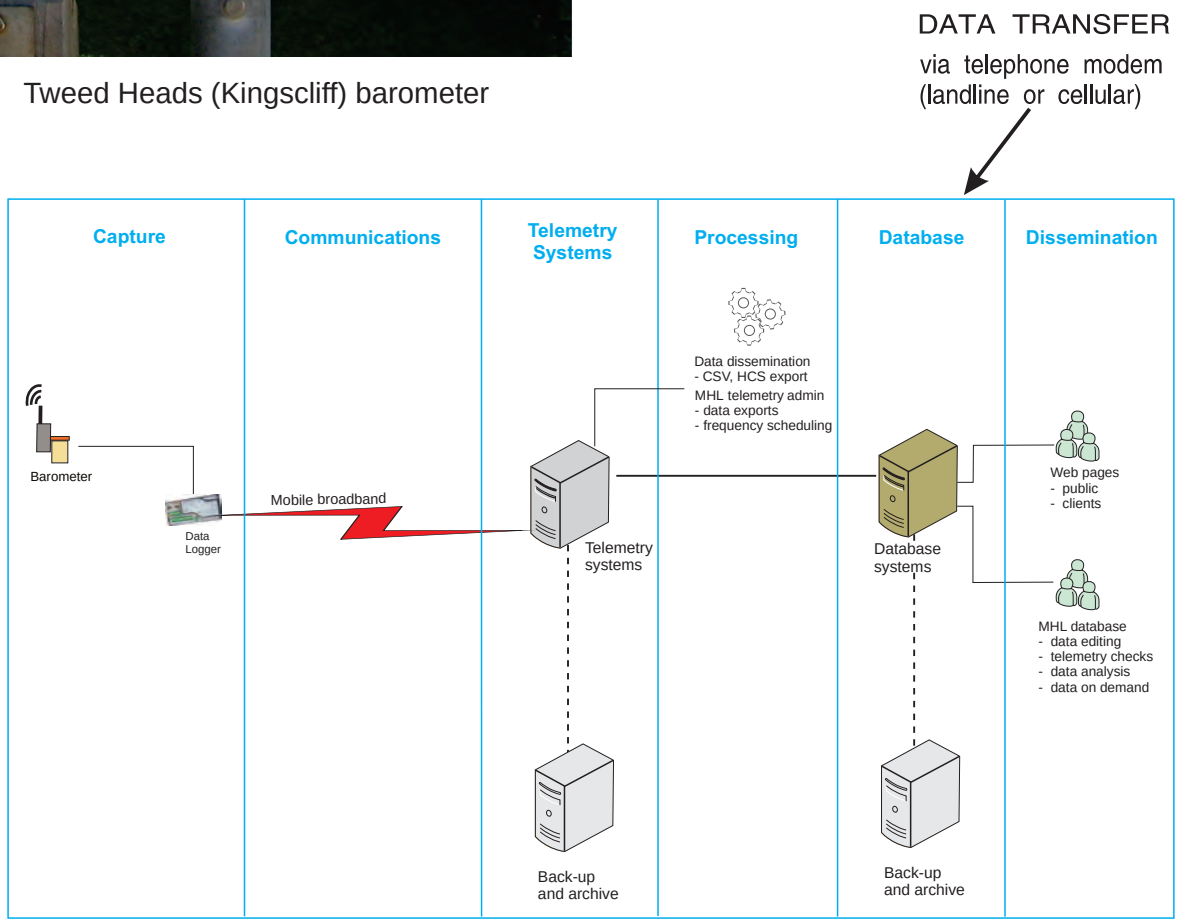
Figure 2.1

DRAWING 2576-02-01.cdr



Tweed Heads (Kingscliff) barometer

Vaisala digital barometer



NSW GOVERNMENT Manly Hydraulics Laboratory

AIR PRESSURE DATA COLLECTION SYSTEM

MHL Report 2576

Figure 2.2

DRAWING 2576-02-02.cdr

3. How to use this report

The wave and air pressure information is organised in a menu style.

From the NSW offshore Waverider buoy location map (Figure 1.1), a reference is given to a detailed station location map for each Waverider site and to the annual time history plots of wave height from which the user can readily check for data availability, storm events, etc.

Annual time history plots of air pressure are referenced from the NSW barometer location map (Figure 2.1).

Once a choice has been made of the duration for which wave or air pressure information is required, a variety of ways exist in which a detailed examination of the data can be made. Samples of the selected data presentation formats are provided in Appendix A.

In addition to the offshore Waverider buoy and air pressure data presented in this summary, details of project-specific sites for which data is available in the same formats are catalogued in Sections 7 and 9.

The appropriate information can then be ordered from the Laboratory.

> THE SITE INFORMATION IN THIS REPORT HAS BEEN PRESENTED AS A CATALOGUE OF DATA FOR EACH SITE. THE GRAPHICAL SCALES HAVE BEEN SELECTED FOR THIS PURPOSE. AT THESE SCALES THE INFORMATION IS NOT NECESSARILY DIRECTLY SUITABLE FOR ANALYSIS PURPOSES. IT IS THEREFORE RECOMMENDED THAT THIS REPORT ONLY BE UTILISED TO SELECT THE DATA SET REQUIRED. THE FORMAT APPROPRIATE TO THE INTENDED USE CAN THEN BE DETERMINED AND THE DATA PRESENTED ACCORDINGLY.

4. How to access the data

Four modes of database access/distribution are available:

- direct access at Manly Hydraulics Laboratory using a screen terminal for data review in plot or table form
- hard copy tables and plots at Manly Hydraulics Laboratory
- data can be provided in digital form by Manly Hydraulics Laboratory by email or on CD/ DVD suitable for transfer to a personal computer
- automated ftp or email distribution from Manly Hydraulics Laboratory to any remote computer.

Quality controlled data can be requested by contacting MHL by email via data-request@mhl.nsw.gov.au

Plots of near-real time wave data and air pressure data for the previous four days can also be accessed by the internet through Manly Hydraulics Laboratory's home page at:

www.mhl.nsw.gov.au

ANY FEES CHARGED BY MANLY HYDRAULICS LABORATORY FOR THE PROVISION OF DATA ONLY INCLUDE QUALITY CONTROL, COMPUTING, SOFTWARE MAINTENANCE AND DISSEMINATION COSTS.

5. Wave climate program summary 2016–2017

5.1 Data capture

Based on offshore wave data recovery achieved by Manly Hydraulics Laboratory over the past 20 years, the target average annual data recovery for all offshore Waverider buoy stations is 85 percent. During normal operations this target is readily achieved by the Waverider buoy network. Any data loss longer than one week is usually due to loss or damage to Waverider buoys by ship collisions. The monthly percentage data capture during 2016–2017 for each Waverider buoy station is provided in Table 5.1.

Table 5.1 New South Wales wave climate: 2016–2017 data capture

Waverider site	Data capture (%)												Total year
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
Byron Bay	93	91	96	80	66	53	0	78	100	100	100	99	**80**
Coffs Harbour	99	99	100	91	99	98	95	96	100	91	89	98	**96**
Crowdy Head	99	99	98	83	95	98	100	100	99	99	98	99	**97**
Sydney	94	98	93	95	98	88	94	96	89	85	96	90	**93**
Port Kembla	81	95	83	72	95	89	92	79	27	67	100	79	**80**
Batemans Bay	94	91	78	97	97	98	99	97	96	82	97	95	**93**
Eden	34	100	98	99	88	89	17	26	98	99	86	99	**78**
Total Months	**85**	**96**	**92**	**88**	**91**	**88**	**71**	**82**	**87**	**89**	**95**	**94**	**88**

Data recovery at three Waverider stations during 2016–2017 was below 85 percent. The higher than average data loss at these stations was due to:

- Byron Bay – the Waverider buoy went adrift on 27 December 2016 resulting in data loss until the buoy was replaced on 7 February 2017. Poor sea conditions during January 2017 delayed the replacement of the Waverider buoy. A GPS tracking device attached to the buoy enabled the successful recovery of the buoy off Newcastle.
- Port Kembla – intermittent submergence of the Waverider buoy due to strong ocean currents and a faulty receiving station computer contributed to poor data capture during March and April 2017.
- Eden – the Waverider buoy went adrift on 6 January 2017. Poor sea conditions during January 2017 delayed the deployment of a replacement buoy until 21 February 2017.

Detailed station location information and data plots for 2016–2017 for all offshore sites are presented in Figures 5.1 to 5.14.

5.2 Storm events

Days on which the significant wave height exceeded 3 metres at each offshore Waverider buoy site are summarised on Figure 5.15.

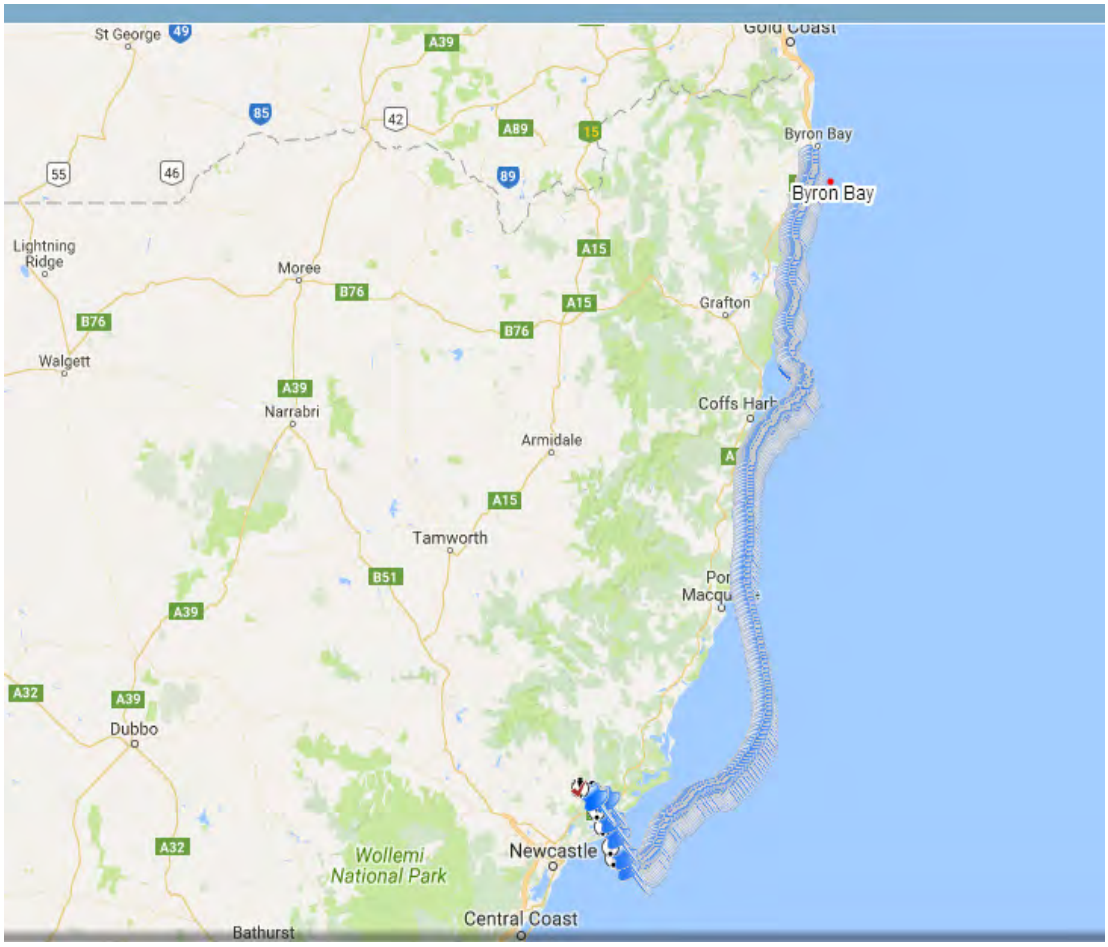
5.3 System down time

A summary of system down time for periods longer than one day for each offshore site is presented on Figure 5.15.

5.4 Significant developments 2016–2017

5.4.1 Waverider buoy tracking by GPS

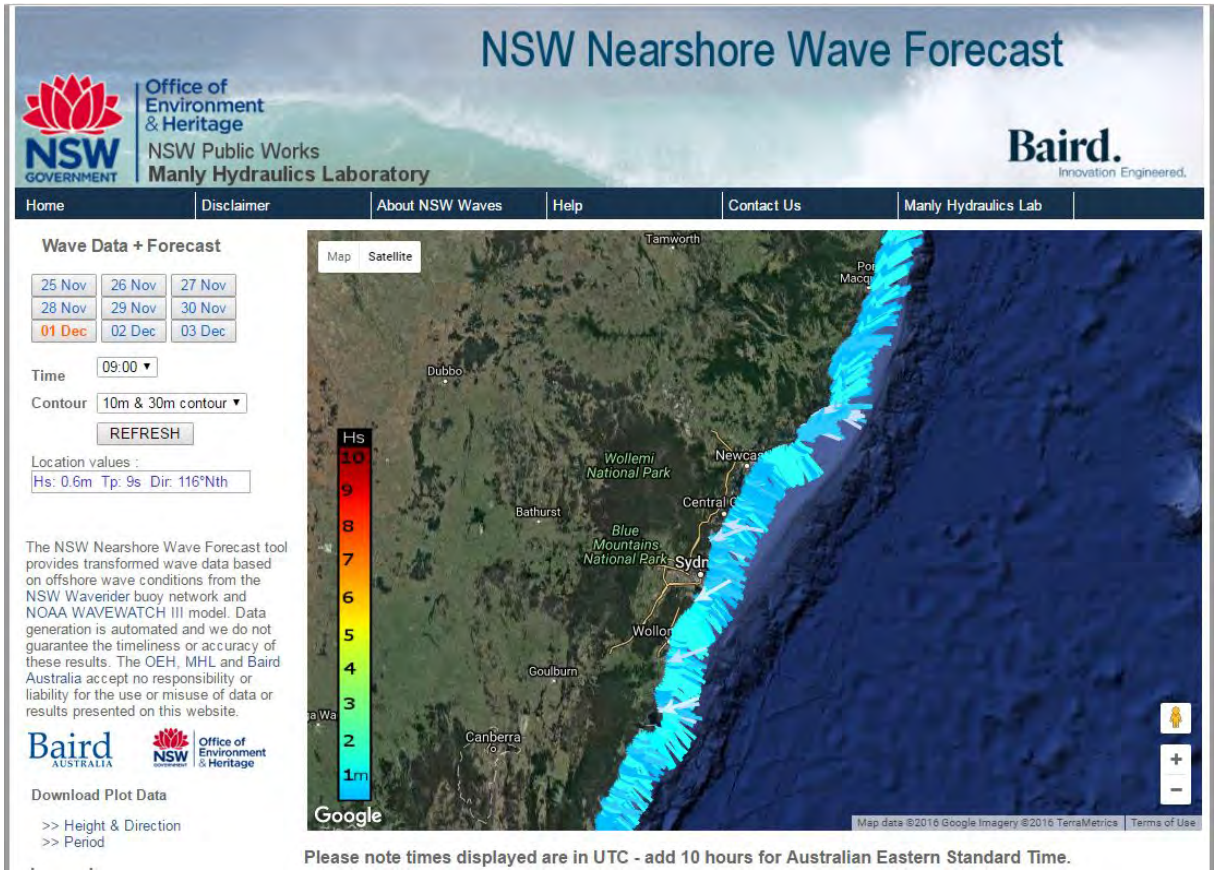
GPS tracking units supplied by Pivotel ® are currently being attached to Waverider buoys to check their position once per day. However, should a buoy move outside a predetermined watch-circle MHL is notified by SMS (on a mobile phone) or by email with position updates every hour. A webpage interface operated by Pivotel allows registered users to configure the operation of the GPS tracking units and plot the location of the NSW Waverider buoys. The successful operation of the tracking units and software resulted in the recovery of a Waverider buoy that went adrift from the Byron Bay station on 27 December 2016. The buoy drifted south under the influence of the East Australian Current before it was recovered approximately 60 km east of Newcastle on 14 January 2017, as shown on the following image extracted from the Pivotel 'Tracertrak' webpage. The Waverider buoy drifted approximately 500 km in 17 days (about 30 km per day) before it was recovered.



The Pivotel GPS tracking device has now been used to recover two adrift Waverider buoys, easily justifying the cost of the tracking devices and operational service fees.

5.4.2 NSW nearshore waves

Further refinement of a numerical nearshore wave transformation toolbox that provides an output of wave conditions near the shoreline along the length of the NSW coast was undertaken. The 'NSW Nearshore Waves' project is a collaboration between OEH, MHL and Baird Australia. The project has developed a suite of tools to efficiently transfer offshore wave conditions measured by the NSW Waverider buoy network, and simulated by global and regional ocean wave models, to nearshore locations along the entire NSW coastline. Nearshore wave conditions over the previous four days at the 10 m depth contour at a spacing of 100 m and at the 30 m depth contour every 1000 m are available. In addition to the output derived from the Waverider buoy network, forecast wave conditions based on six-hourly data from the Wave Watch 3 (WW3) wave forecasting model are available for three days into the future. A screen shot of the NSW Nearshore Waves homepage follows.



The NSW Nearshore Waves webpage is:

http://nearshore.waves.nsw.gov.au

5.4.3 Upgrade of Waverider buoys

Prior to 2016–2017 the NSW Waverider buoy network was comprised of a mix of MK2 and MK3 Datawell Directional Waverider buoys. Upgrade to a fully MK3 buoy network was completed during 2016–2017. The MK3 Waverider buoys include a GPS receiver enabling the buoys to routinely transmit location information to the shore receiving station. However, if a buoy moves beyond the radio signal range of the receiving station (approximately 50 km) the GPS location is not available at the receiving station and MHL. This shortcoming was addressed with the introduction of the Pivotel satellite-based GPS tracking devices to monitor the location of Waverider buoys anywhere off the NSW coast.

The MK3 Directional Waverider buoys also include an on-board data logger that records wave data to an industrial grade CF memory card. This feature enables data to be processed after the recovery of the buoy to patch extended periods of data loss due to telemetry or receiving station instrumentation failures.

5.4.4 Extreme wave analysis

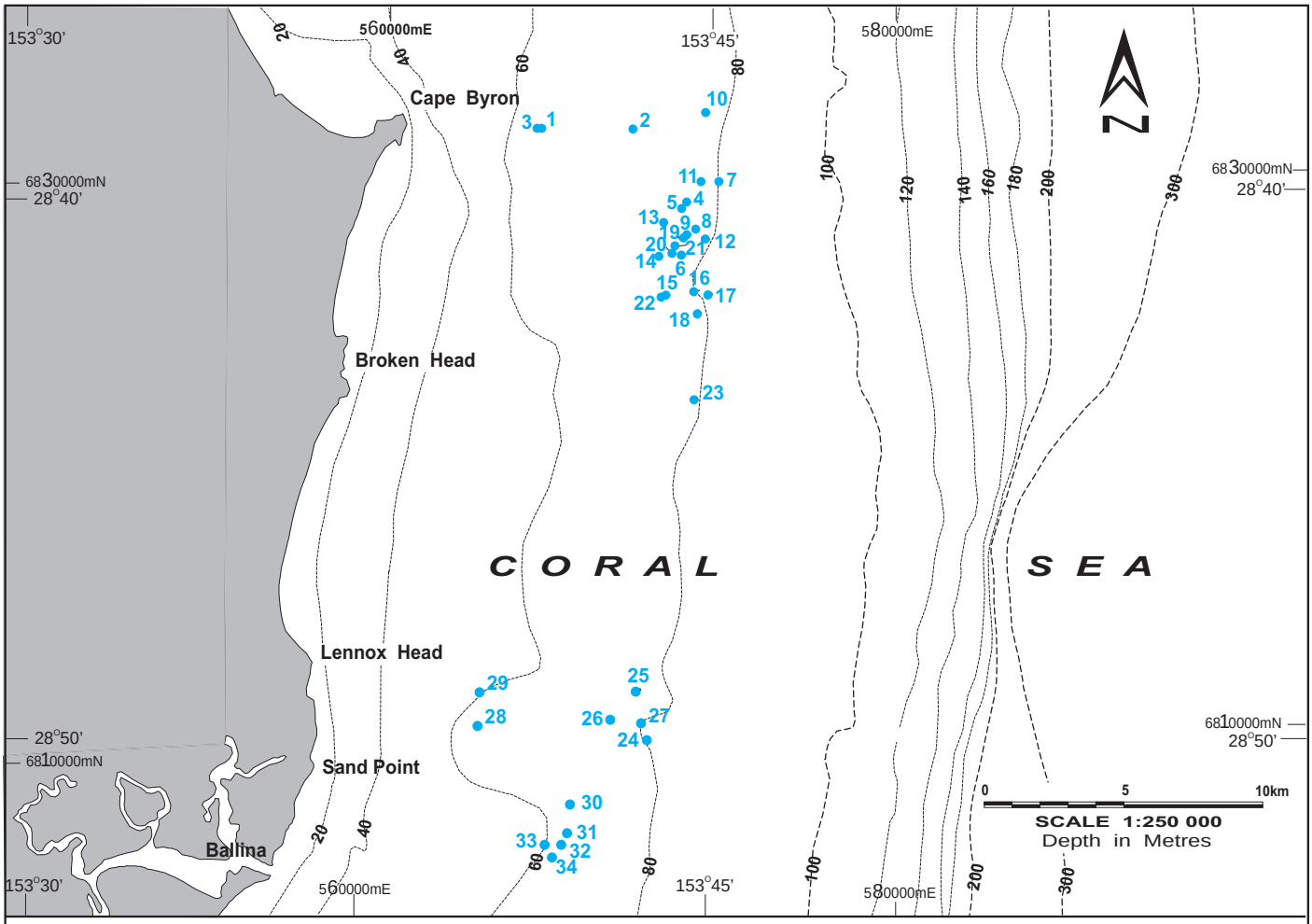
The last comprehensive analysis of NSW ocean storm wave data was undertaken in 2010. Since that time there have been several major coastal storms with all Waverider stations recording at least one storm event in the top five of all events recorded. These wave records are, therefore, missing from the extreme value analysis of wave heights currently used for the design of NSW coastal structures and coastal management purposes. During 2016–2017 an update of the 2010 extreme wave height analysis commenced which will result in the issue of a technical report detailing the analysis methodology and study results in 2017–2018.

5.5 Future developments 2017–2018

MHL will be upgrading the data delivery mechanism for data originating from the Waverider buoy network. This network will interface to MHL's cloud environment, reducing reliance on mail delivery systems outside of MHL's ICT Service Level Agreement.

MHL has recently implemented a highly optimised database for the storage of time series data in the cloud. These systems benefit from cloud architecture distributing systems across various physical data centres to provide a High Availability solution. A public Application Program Interface (API) is planned for accessing the wave data. This API will be suitable for web applications and map-based applications.

The NSW offshore wave data contributes to various downstream users and systems. MHL is responsible for disseminating these wave data in a range of formats. To simplify and extend the ability to format and present wave data, MHL will be implementing an Enterprise Service Bus style software solution in its cloud-based Data Processing Environment.



DEPLOYMENT LOCATION	LOCATION DETAILS				WATER DEPTH (m)	DEPLOYMENT PERIOD	
	Latitude (S)	Longitude (E)	MGA (Zone 56J) Easting	MGA (Zone 56J) Northing		First Date	Last Date
1	28°38'24"	153°41'18"	567280	6831690	64	14-Oct-1976	07-Jun-1978
2	28°38'24"	153°43'18"	570530	6831670	70	03-Aug-1978	13-Jun-1979
3	28°38'24"	153°41'12"	567110	6831690	62	08-Aug-1979	09-Aug-1983
4	28°39'48"	153°44'30"	572470	6829080	77	09-Aug-1983	13-Dec-1983
5	28°39'54"	153°44'24"	572310	6828890	77	07-Feb-1984	25-Sep-1984
6	28°40'48"	153°44'24"	572300	6827230	73	25-Sep-1984	30-Jun-1985
7	28°39'24"	153°45'12"	573620	6829810	80	27-Aug-1985	22-Nov-1985
8	28°40'18"	153°44'42"	572790	6828140	78	12-Dec-1985	24-Mar-1987
9	28°40'25"	153°44'31"	572480	6827950	78	24-Mar-1987	19-Nov-1987
10	28°38'05"	153°44'54"	573150	6832250	77	03-Dec-1987	07-Apr-1988
11	28°39'24"	153°44'49"	572980	6829800	77	18-May-1988	07-Nov-1988
12	28°40'30"	153°44'55"	573130	6827780	82	06-Dec-1988	08-Dec-1988
13	28°40'12"	153°44'00"	571650	6828350	72	10-Jan-1989	05-Aug-1989
14	28°40'49"	153°43'55"	571500	6827200	71	29-Aug-1989	14-Dec-1989
15	28°41'35"	153°44'03"	571730	6825790	74	07-Feb-1990	06-Dec-1990
16	28°41'30"	153°44'40"	572730	6825950	73	06-Dec-1990	08-May-1991
17	28°41'33"	153°44'59"	573240	6825840	78	29-May-1991	14-May-1992
18	28°41'55"	153°44'46"	572880	6825170	73	14-May-1992	18-Jun-1993
19	28°40'28"	153°44'26"	572360	6827850	73	23-Jun-1993	21-Jul-1993
20	28°40'46"	153°44'12"	571970	6827300	72	21-Jul-1993	11-Nov-1993
21	28°40'37"	153°44'15"	572060	6827570	72	01-Dec-1993	20-Jul-1994
22	28°41'36"	153°43'57"	571560	6825760	72	20-Jul-1994	05-Feb-1996
23	28°43'32"	153°44'40"	572700	6822180	72	05-Feb-1996	28-Nov-2001
24	28°50'09"	153°43'43"	571080	6809970	71	29-Nov-2000	23-Jan-2001
25	28°49'14"	153°43'38"	570950	6811670	71	10-Feb-2001	29-Aug-2003
26	28°49'44"	153°43'08"	570030	6810570	71	29-Aug-2003	12-Aug-2004
27	28°50'02"	153°43'24"	570570	6810200	71	12-Aug-2004	01-Jan-2005
28	28°49'36"	153°39'48"	564720	6811040	62	04-Feb-2005	11-Dec-2007
29	28°49'21"	153°39'56"	564940	6811500	62	11-Dec-2007	20-Aug-2009
30	28°51'14"	153°42'07"	568470	6808000	62	20-Aug-2009	11-Feb-2012
31	28°51'58"	153°42'00"	568270	6806650	62	11-Feb-2012	05-Oct-2012
32	28°52'04"	153°41'39"	567600	6806540	62	16-Oct-2012	15-Nov-2013
33	28°51'58"	153°41'29"	567430	6806650	62	15-Nov-2013	29-May-2014
34	28°52'14"	153°41'39"	567700	6806160	62	29-May-2014	Present

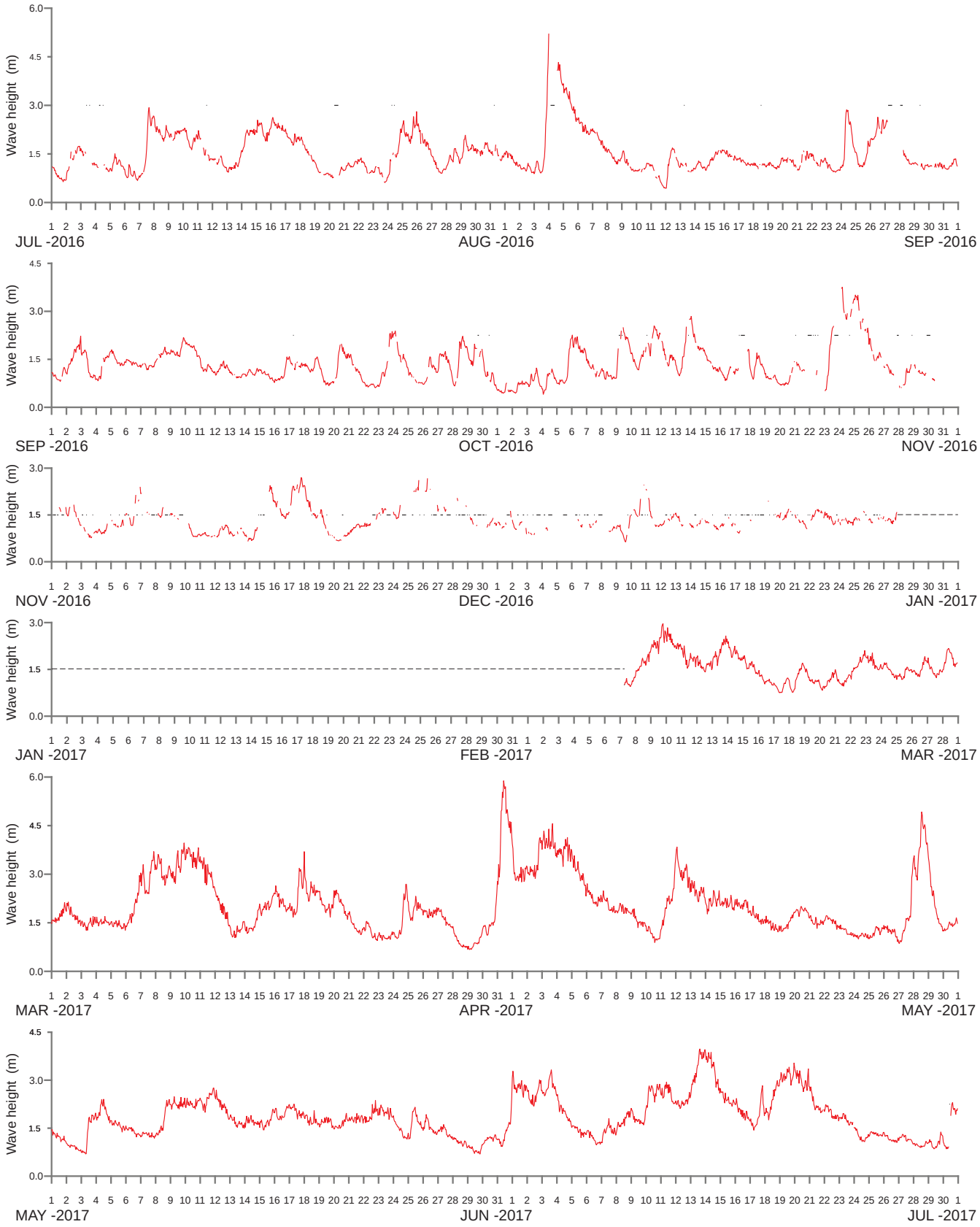
NSW GOVERNMENT Manly Hydraulics Laboratory

BYRON BAY WAVERIDER BUOY LOCATION HISTORY

MHL Report 2576

Figure 5.1

DRAWING 2576-05-01.cdr



DATA LOSS

Manly Hydraulics Laboratory

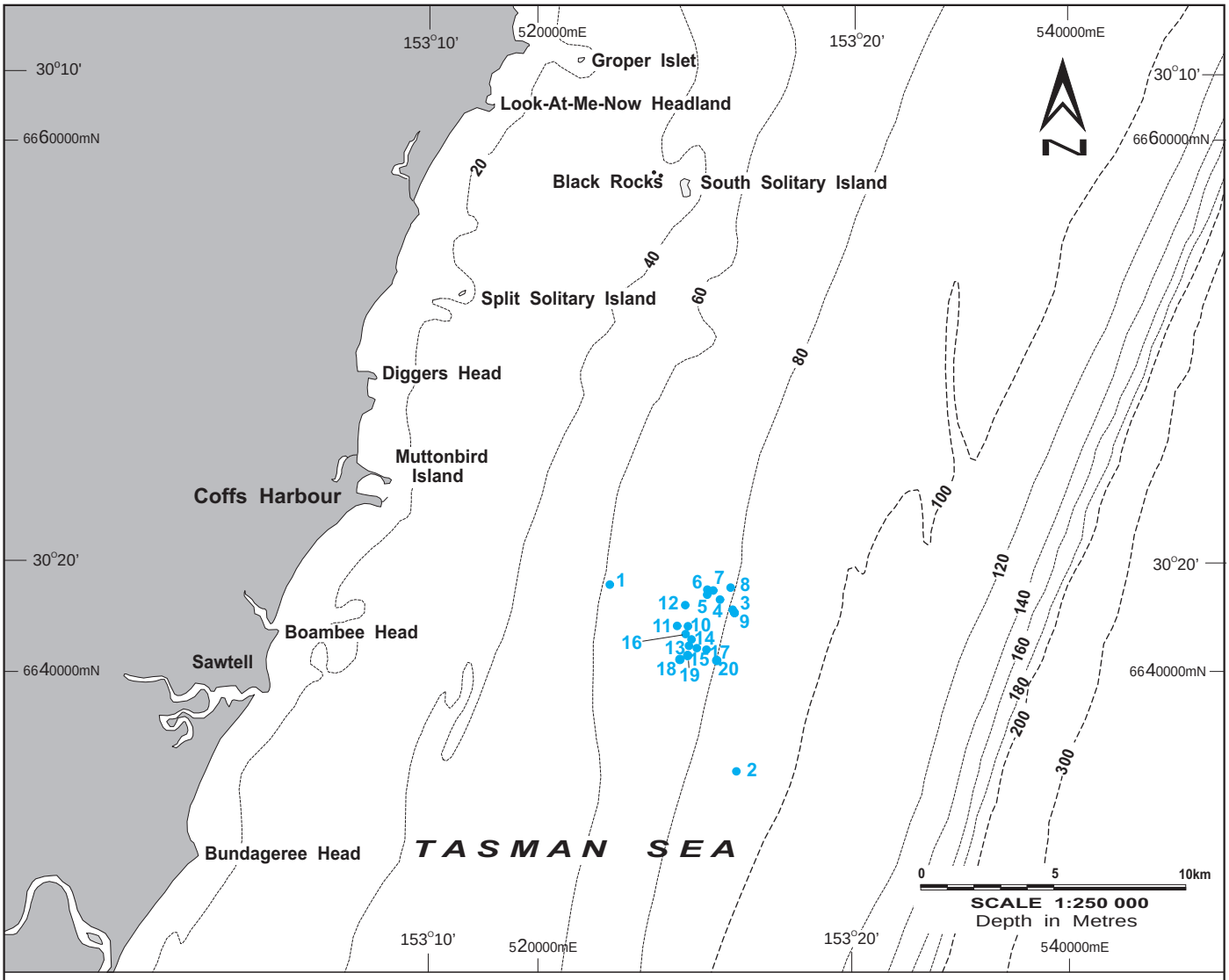
NSW GOVERNMENT

BYRON BAY WAVERIDER BUOY
2016–2017 SIGNIFICANT WAVE HEIGHT TIME HISTORY

MHL Report 2576

Figure 5.2

DRAWING 2576-05-02.cdr



DEPLOYMENT LOCATION	LOCATION DETAILS				WATER DEPTH (m)	DEPLOYMENT PERIOD	
	Latitude (S)	Longitude (E)	MGA (Zone 56J) Easting	Northing		First Date	Last Date
1	30°20'30"	153°14'12"	522750	6643320	60	26-May-1976	18-Aug-1983
2	30°24'18"	153°17'12"	527540	6636290	80	18-Aug-1983	20-Dec-1983
3	30°21'00"	153°17'06"	527390	6642380	80	20-Dec-1983	07-Mar-1984
4	30°20'48"	153°16'48"	526910	6642760	79	07-Mar-1984	12-Apr-1985
5	30°20'42"	153°16'30"	526430	6642940	77	12-Apr-1985	09-Jul-1985
6	30°20'36"	153°16'30"	526430	6643130	77	13-Aug-1985	29-Oct-1985
7	30°20'37"	153°16'38"	526640	6643100	77	05-Nov-1985	08-Oct-1987
8	30°20'34"	153°17'03"	527300	6643200	80	08-Oct-1987	25-Sep-1989
9	30°21'04"	153°17'08"	527450	6642250	82	25-Sep-1989	06-Dec-1989
10	30°21'21"	153°16'03"	525700	6641750	71	19-Dec-1989	11-Apr-1990
11	30°21'20"	153°15'48"	525300	6641770	73	11-Apr-1990	22-Feb-1991
12	30°20'55"	153°15'59"	525600	6642550	73	22-Feb-1991	02-Jul-1996
13	30°21'46"	153°16'04"	525730	6640970	74	26-Jul-1996	06-Dec-1997
14	30°21'37"	153°16'09"	525870	6641250	72	18-Jan-1998	07-Nov-2002
15	30°21'36"	153°16'22"	526210	6641280	72	23-Nov-2002	11-Mar-2005
16	30°21'25"	153°16'07"	525920	6641810	72	01-Apr-2005	19-Oct-2009
17	30°21'41"	153°16'11"	525920	6641140	72	19-Oct-2009	13-Feb-2012
18	30°22'22"	153°15'32"	524880	6639880	72	13-Feb-2012	26-Oct-2013
19	30°21'45"	153°16'09"	525870	6641010	72	26-Oct-2013	18-Aug-2016
20	30°22'03"	153°16'40"	526590	6640450	72	18-Aug-2016	Present

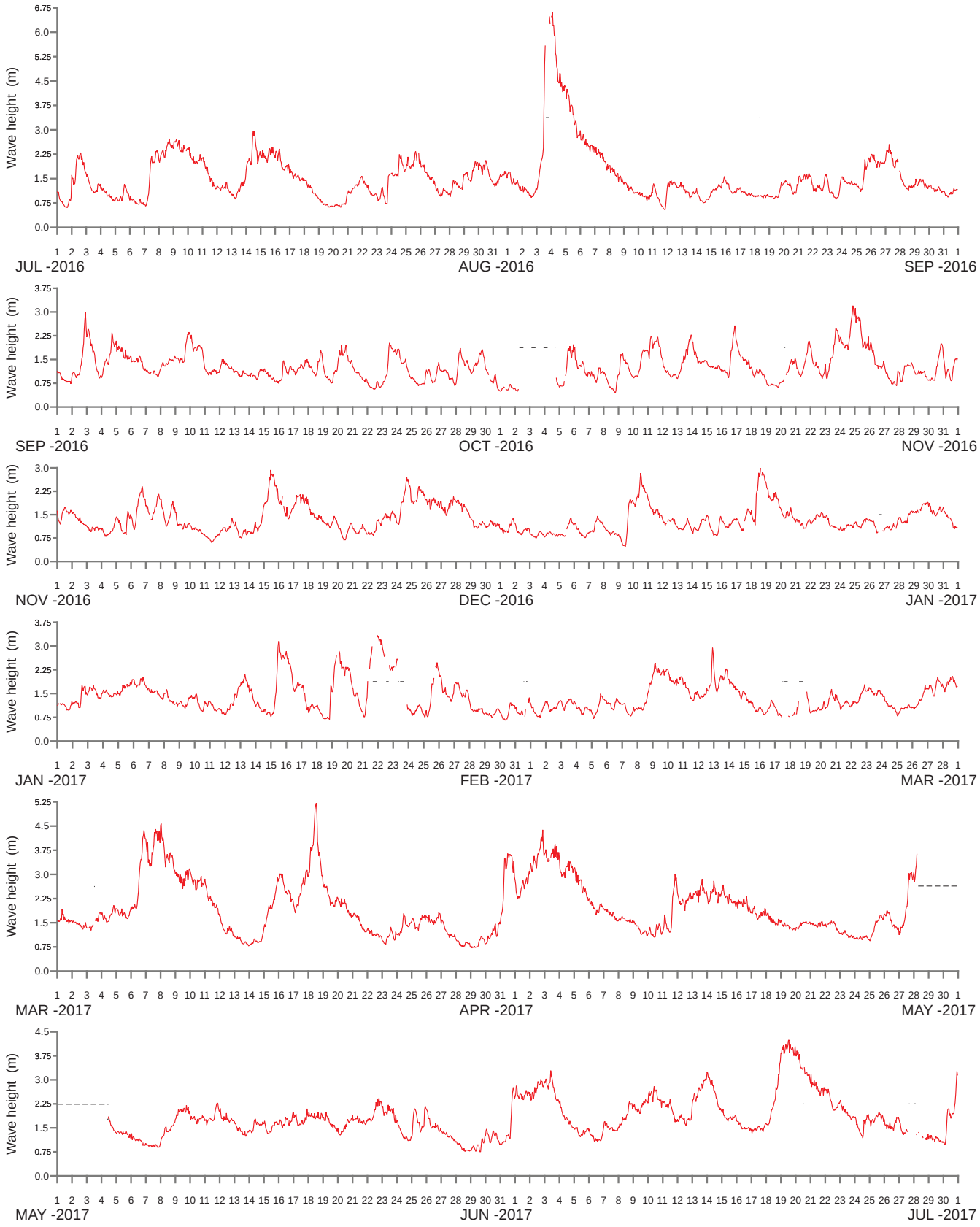
NSW GOVERNMENT Manly Hydraulics Laboratory

COFFS HARBOUR WAVERIDER BUOY LOCATION HISTORY

MHL Report 2576

Figure 5.3

DRAWING 2576-05-03.cdr



DATA LOSS

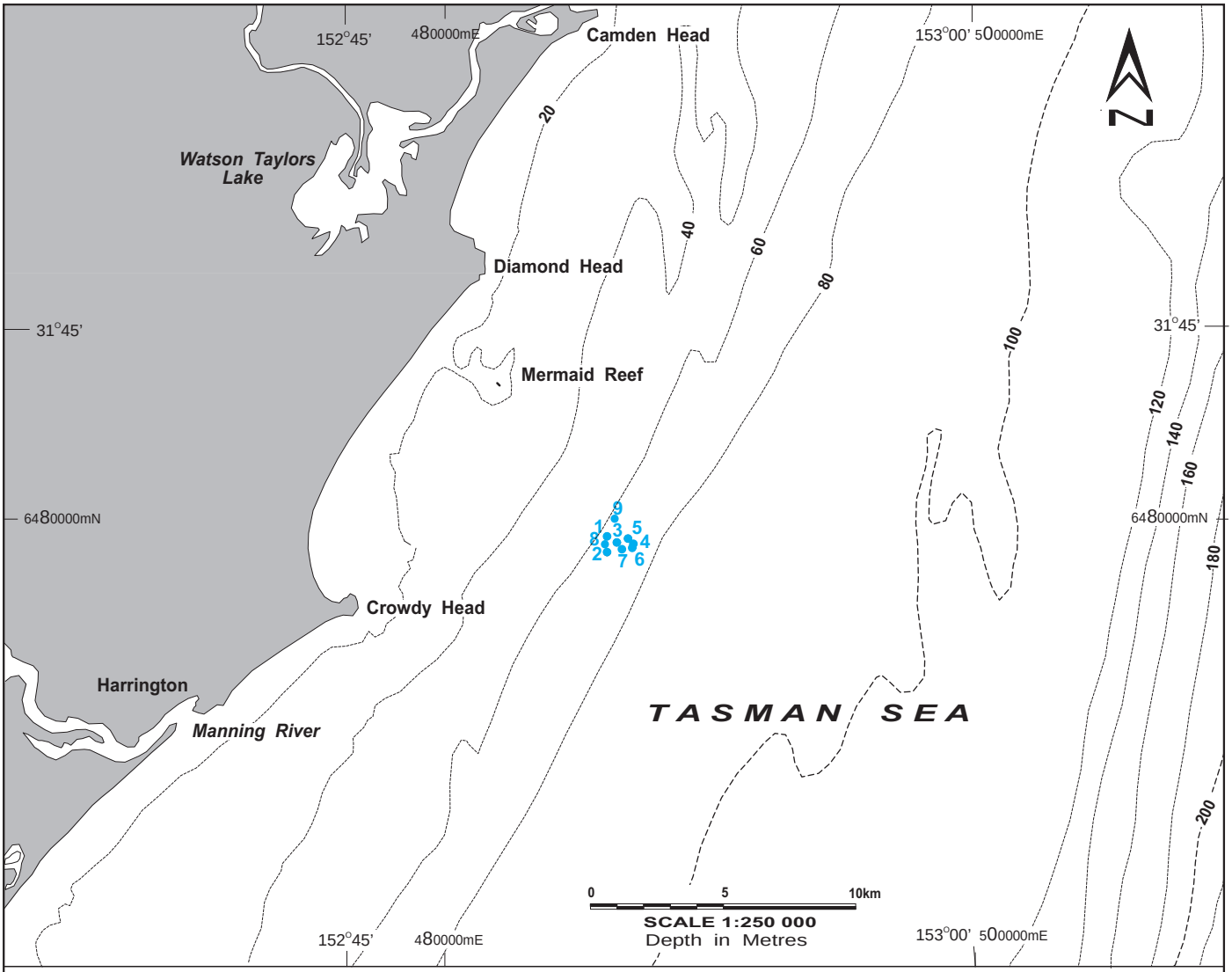
Manly Hydraulics Laboratory
NSW GOVERNMENT

COFFS HARBOUR WAVERIDER BUOY 2016–2017 SIGNIFICANT WAVE HEIGHT TIME HISTORY

MHL Report 2576

Figure 5.4

DRAWING 2576-05-04.cdr



DEPLOYMENT LOCATION	LOCATION DETAILS				WATER DEPTH (m)	DEPLOYMENT PERIOD	
	Latitude (S)	Longitude (E)	MGA (Zone 56J) Easting	Northing		First Date	Last Date
1	31°49'37"	152°51'12"	486110	6478730	77	10-Oct-1985	11-Nov-1986
2	31°49'17"	152°51'12"	486110	6479330	77	11-Nov-1986	20-Oct-1987
3	31°49'25"	152°51'26"	486480	6479100	80	20-Oct-1987	08-Aug-1989
4	31°49'26"	152°51'49"	487100	6479050	79	08-Aug-1989	17-Jul-1990
5	31°49'20"	152°51'42"	486900	6479250	77	17-Jul-1990	20-Apr-1993
6	31°49'31"	152°51'47"	487050	6478900	79	20-Apr-1993	21-Nov-1997
7	31°49'31"	152°51'35"	486720	6478910	79	21-Nov-1997	31-Oct-2012
8	31°49'26"	152°51'08"	485910	6479140	79	30-Oct-2012	04-Jul-2013
9	31°48'50"	152°51'22"	486380	6480180	79	10-Jul-2013	Present

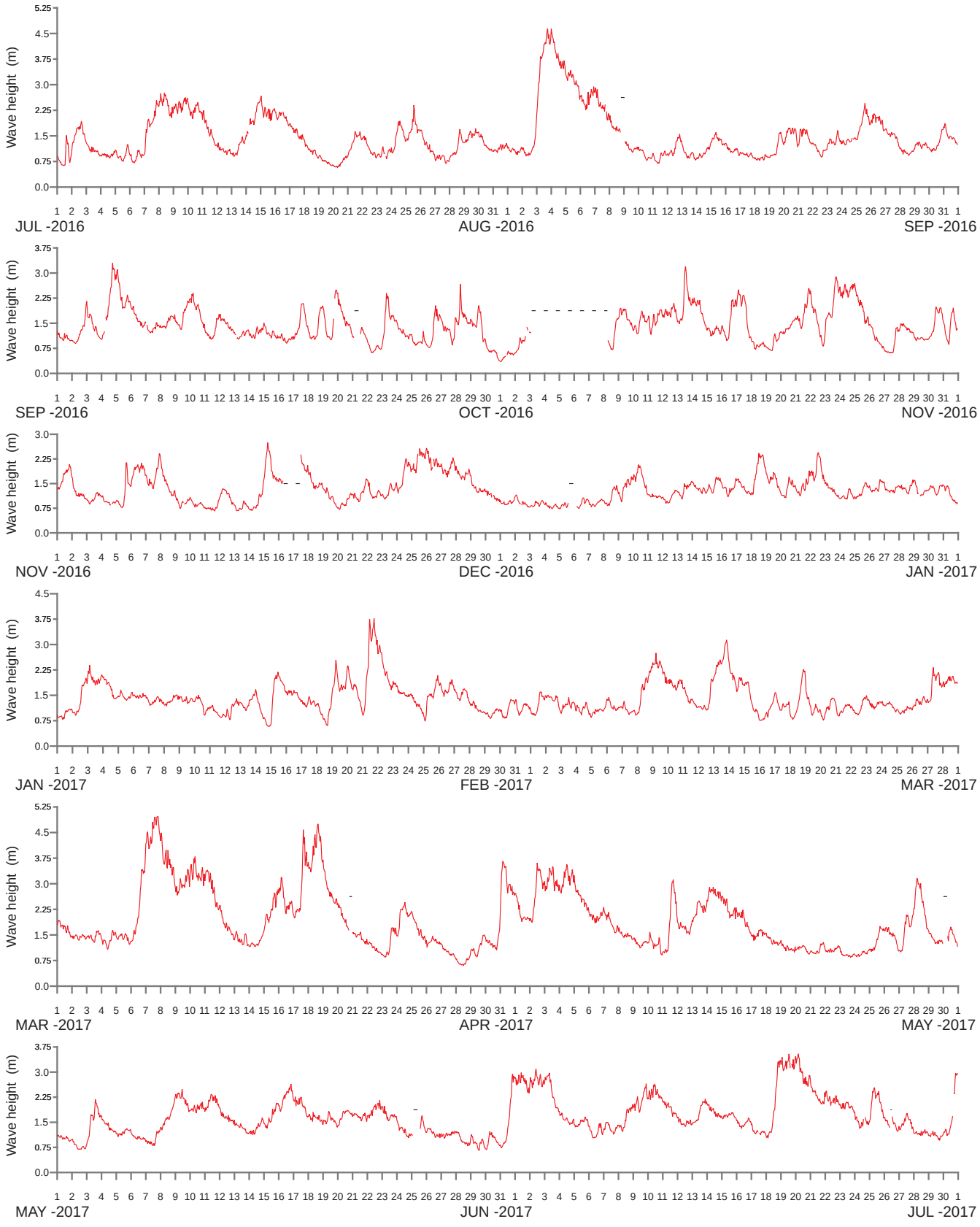
NSW GOVERNMENT Manly Hydraulics Laboratory

CROWDY HEAD WAVERIDER BUOY
LOCATION HISTORY

MHL Report 2576

Figure 5.5

DRAWING 2576-05-05.cdr



DATA LOSS

Manly Hydraulics Laboratory

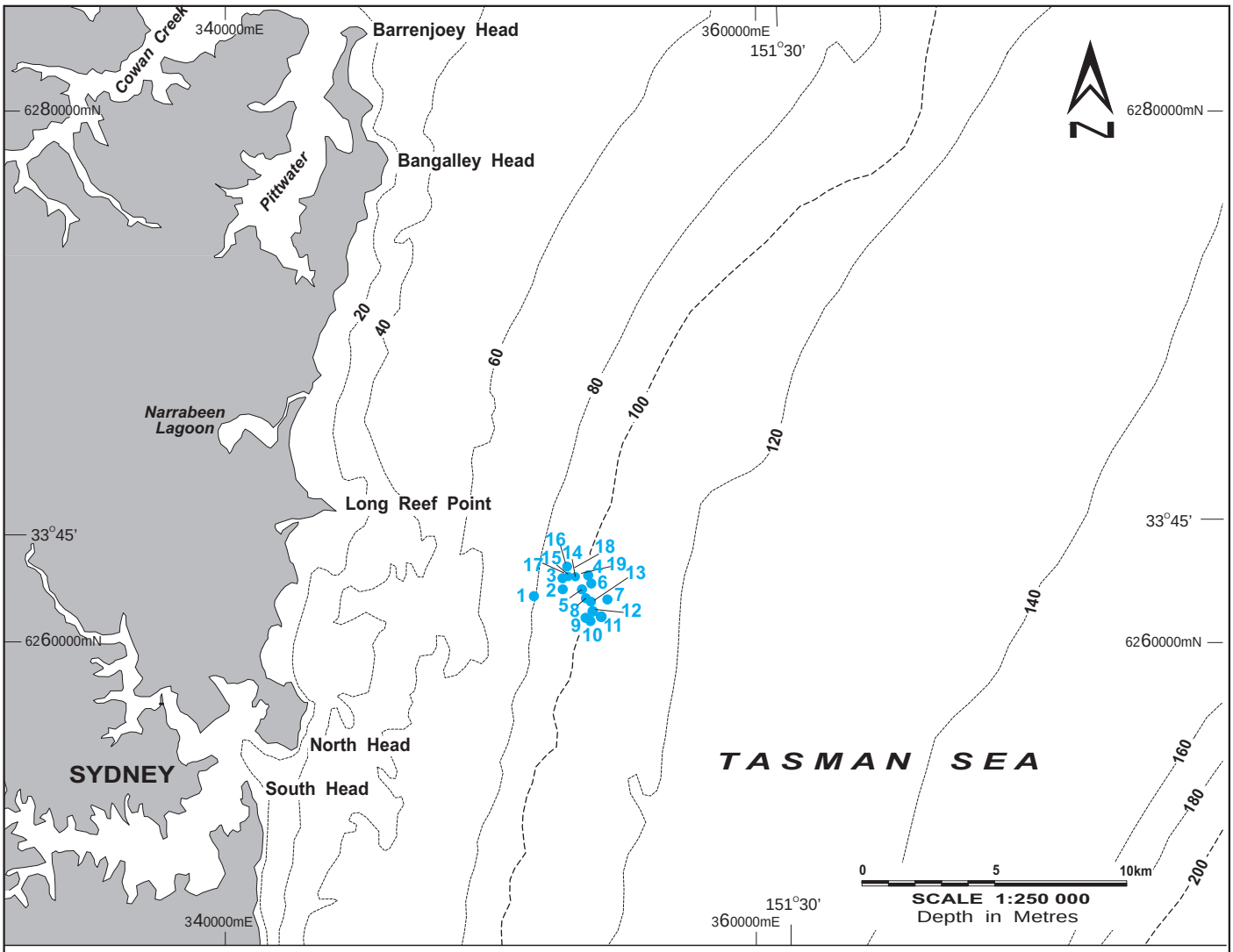
NSW GOVERNMENT

CROWDY HEAD WAVERIDER BUOY
2016–2017 SIGNIFICANT WAVE HEIGHT
TIME HISTORY

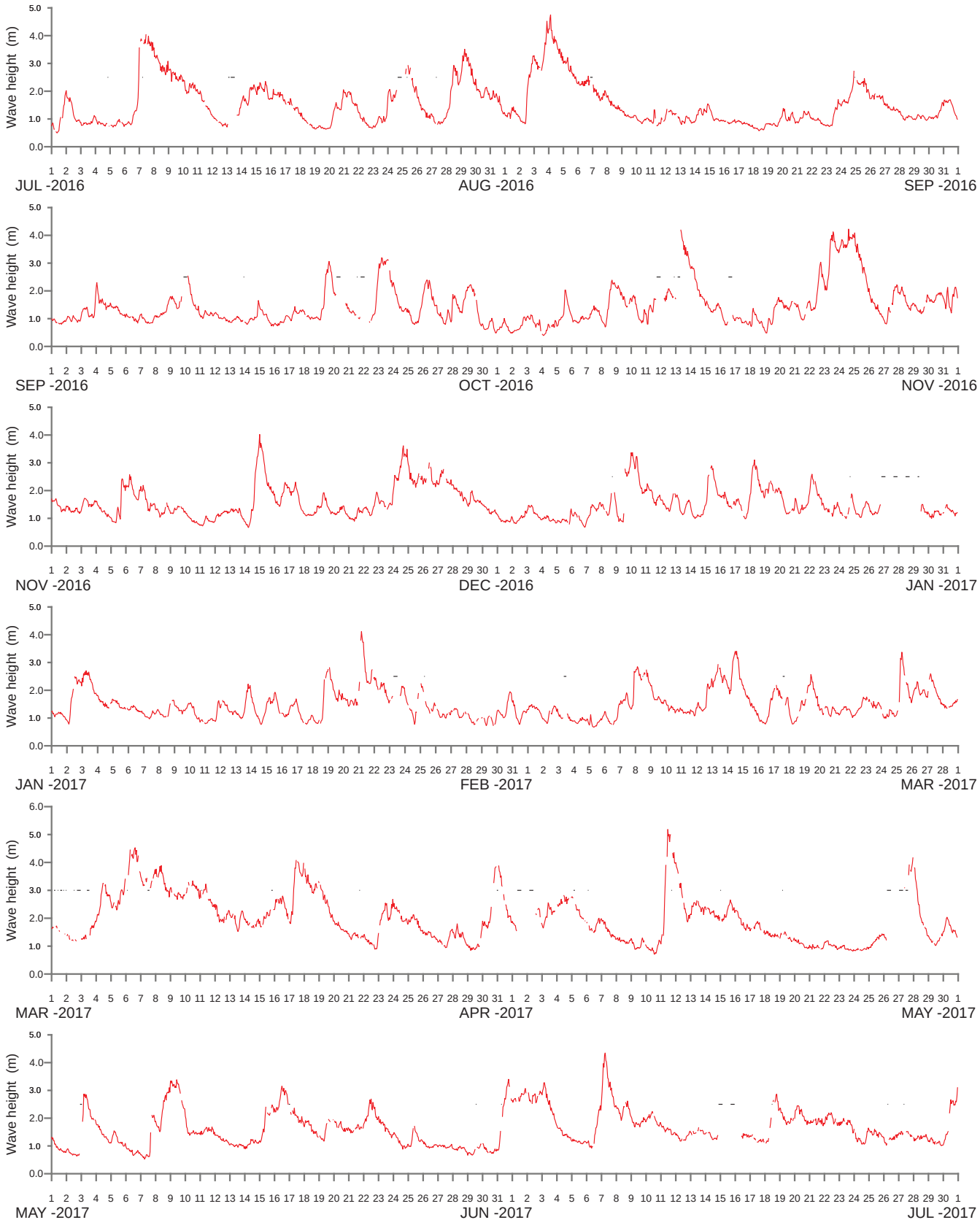
MHL Report 2576

Figure 5.6

DRAWING 2576-05-06.cdr



DEPLOYMENT LOCATION	LOCATION DETAILS				WATER DEPTH (m)	DEPLOYMENT PERIOD	
	Latitude (S)	Longitude (E)	GMA (Zone 56H) Easting	Northing		First Date	Last Date
1	33°46'26"	151°23'52"	351650	6261750	82	03-Mar-1992	05-Apr-1993
2	33°46'18"	151°24'35"	352740	6262010	85	22-Jun-1993	17-Nov-1993
3	33°46'04"	151°24'36"	352760	6262440	85	17-Nov-1993	01-Dec-1993
4	33°46'02"	151°25'13"	353710	6262520	85	18-Dec-1993	16-Feb-1994
5	33°46'17"	151°25'03"	353460	6262050	85	22-Mar-1994	25-Feb-1995
6	33°46'11"	151°25'18"	353840	6262230	87	25-Feb-1995	11-Feb-1998
7	33°46'31"	151°25'39"	354400	6261640	87	11-Feb-1998	01-Oct-1998
8	33°46'29"	151°25'07"	353570	6261680	85	01-Oct-1998	07-Feb-1999
9	33°46'53"	151°25'09"	353630	6260940	85	26-Mar-1999	23-Nov-1999
10	33°46'57"	151°25'17"	353830	6260840	85	23-Nov-1999	20-Jul-2001
11	33°46'54"	151°25'29"	354160	6260930	85	11-Sep-2001	18-May-2004
12	33°46'45"	151°25'15"	354160	6260930	85	18-May-2004	15-Jan-2005
13	33°46'31"	151°25'04"	353490	6261620	85	15-Feb-2005	13-Mar-2008
14	33°46'18"	151°24'59"	353360	6262020	92	13-Mar-2008	25-Nov-2009
15	33°46'08"	151°24'43"	352940	6262340	92	25-Nov-2009	21-Aug-2012
16	33°45'56"	151°24'39"	352830	6262710	92	21-Aug-2012	24-Apr-2014
17	33°46'18"	151°24'31"	352630	6262020	90	24-Apr-2014	30-Oct-2014
18	33°45'51"	151°24'44"	352970	6262860	90	30-Oct-2014	11-Feb-2015
19	33°46'26"	151°24'42"	352920	6261800	90	11-Feb-2015	Present



DATA LOSS

Manly Hydraulics Laboratory

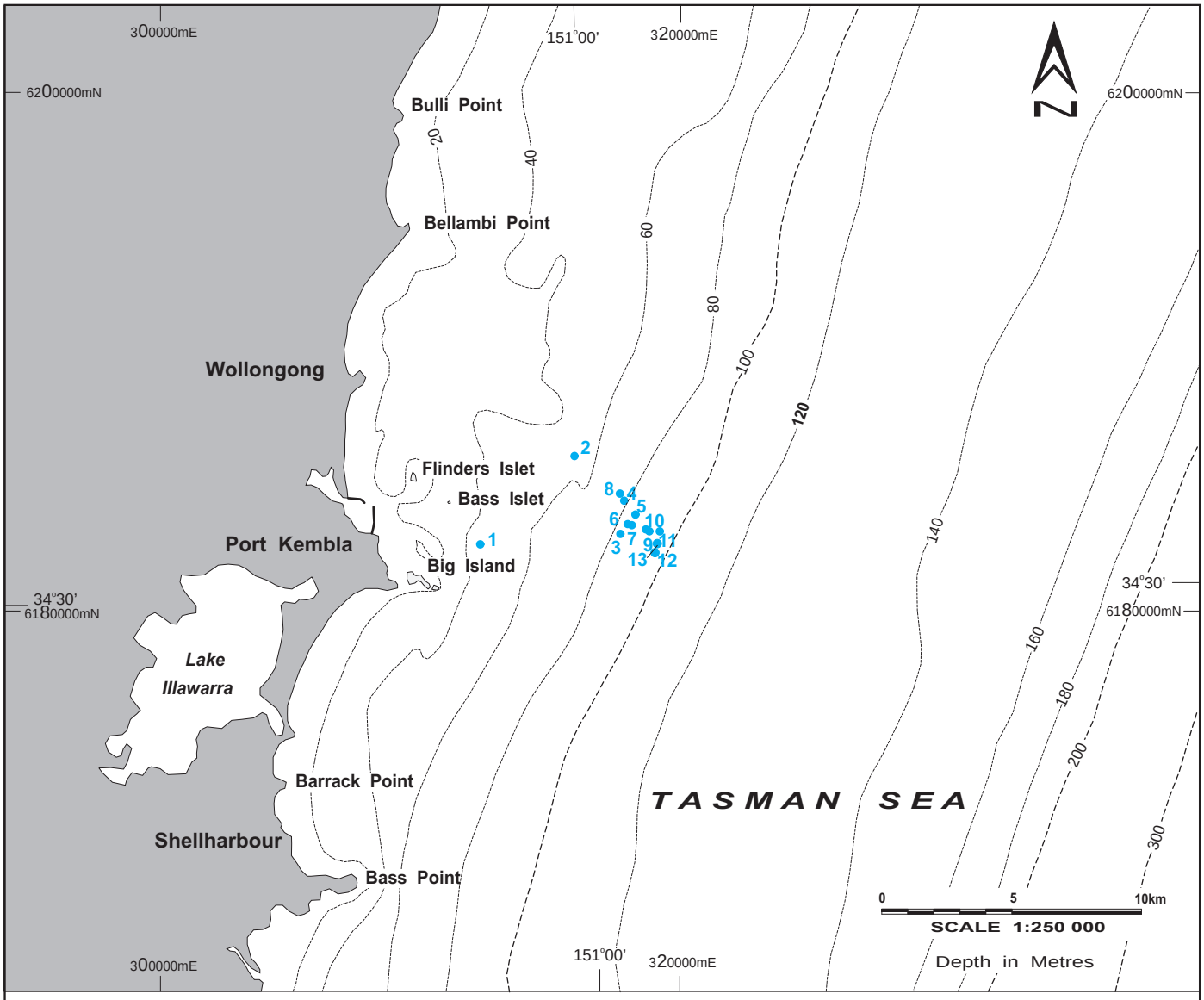
NSW GOVERNMENT

SYDNEY WAVERIDER BUOY
2016–2017 SIGNIFICANT WAVE HEIGHT TIME HISTORY

MHL Report 2576

Figure 5.8

DRAWING 2576-05-08.cdr



DEPLOYMENT LOCATION	LOCATION DETAILS				WATER DEPTH (m)	DEPLOYMENT PERIOD	
	Latitude (S)	Longitude (E)	MGA (Zone 56H) Easting	Northing		First Date	Last Date
1	34°28'52"	150°57'22"	312310	6182590	40	07-Feb-1974	25-Oct-1976
2	34°27'04"	150°59'47"	315940	6185990	50	25-Oct-1976	16-Nov-1983
3	34°28'42"	151°00'54"	317710	6183000	82	16-Nov-1983	14-Jun-1984
4	34°28'01"	151°01'00"	317850	6184280	76	14-Jun-1984	27-May-1988
5	34°28'18"	151°01'18"	318300	6183750	73	01-Jun-1988	19-Dec-1988
6	34°28'30"	151°01'06"	318000	6183380	73	19-Jan-1989	25-Jan-1990
7	34°28'32"	151°01'12"	318150	6183330	77	25-Jan-1990	24-Oct-1991
8	34°27'52"	151°00'55"	317700	6184550	82	24-Oct-1991	24-Jun-1992
9	34°28'24"	151°01'23"	318820	6183090	77	24-Jun-1992	28-Jul-1994
10	34°28'38"	151°01'31"	318650	6183150	78	28-Jul-1994	10-Jun-2003
11	34°28'28"	151°01'34"	318720	6183460	80	25-Jun-2003	15-Jun-2012
12	34°28'19"	151°01'18"	318310	6183740	80	15-Jun-2012	07-Nov-2014
13	34°28'35"	151°01'33"	318700	6183250	80	07-Nov-2014	Present

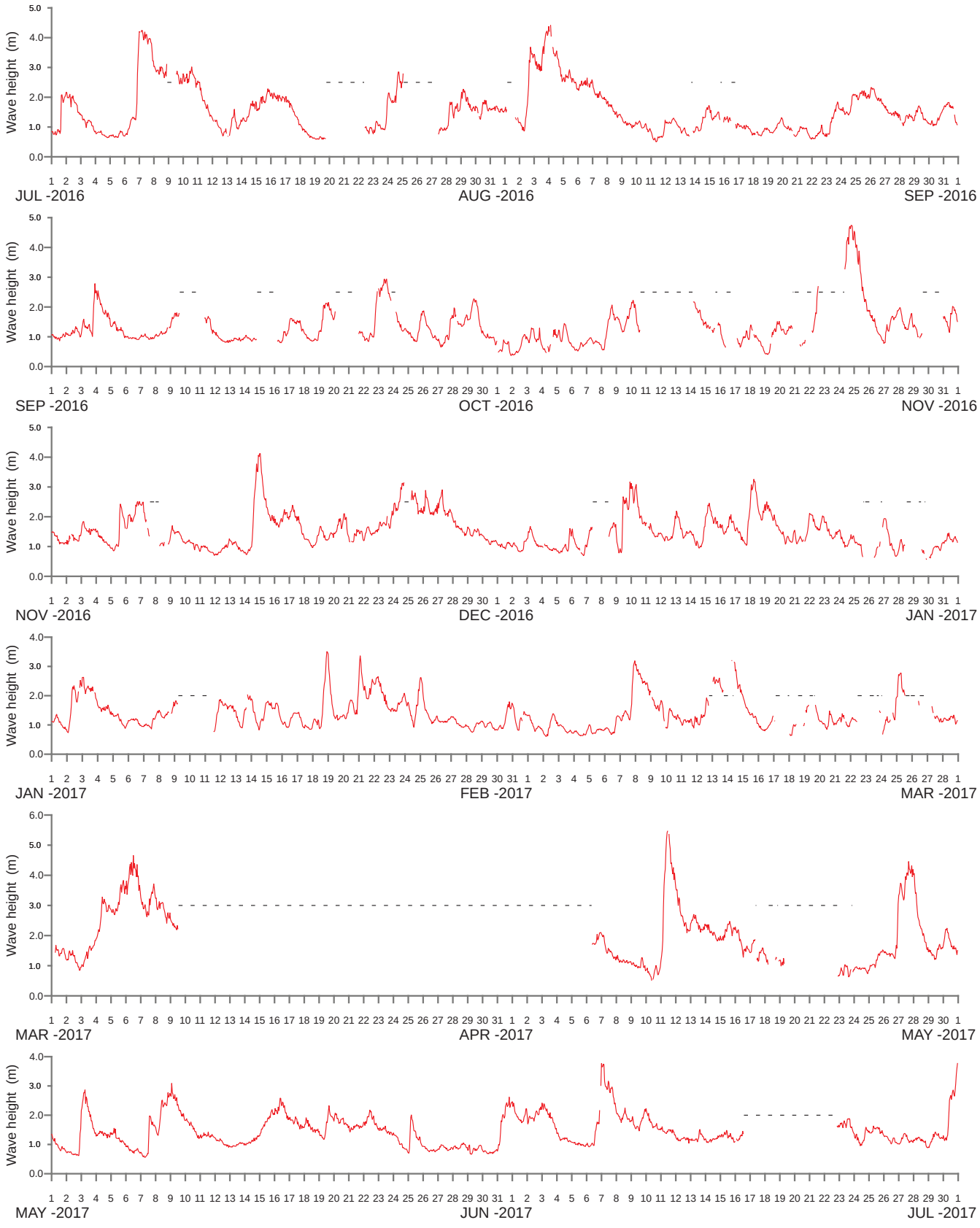
NSW GOVERNMENT Manly Hydraulics Laboratory

PORT KEMBLA WAVERIDER BUOY LOCATION HISTORY

MHL Report 2576

Figure 5.9

DRAWING 2576-05-09.cdr



DATA LOSS

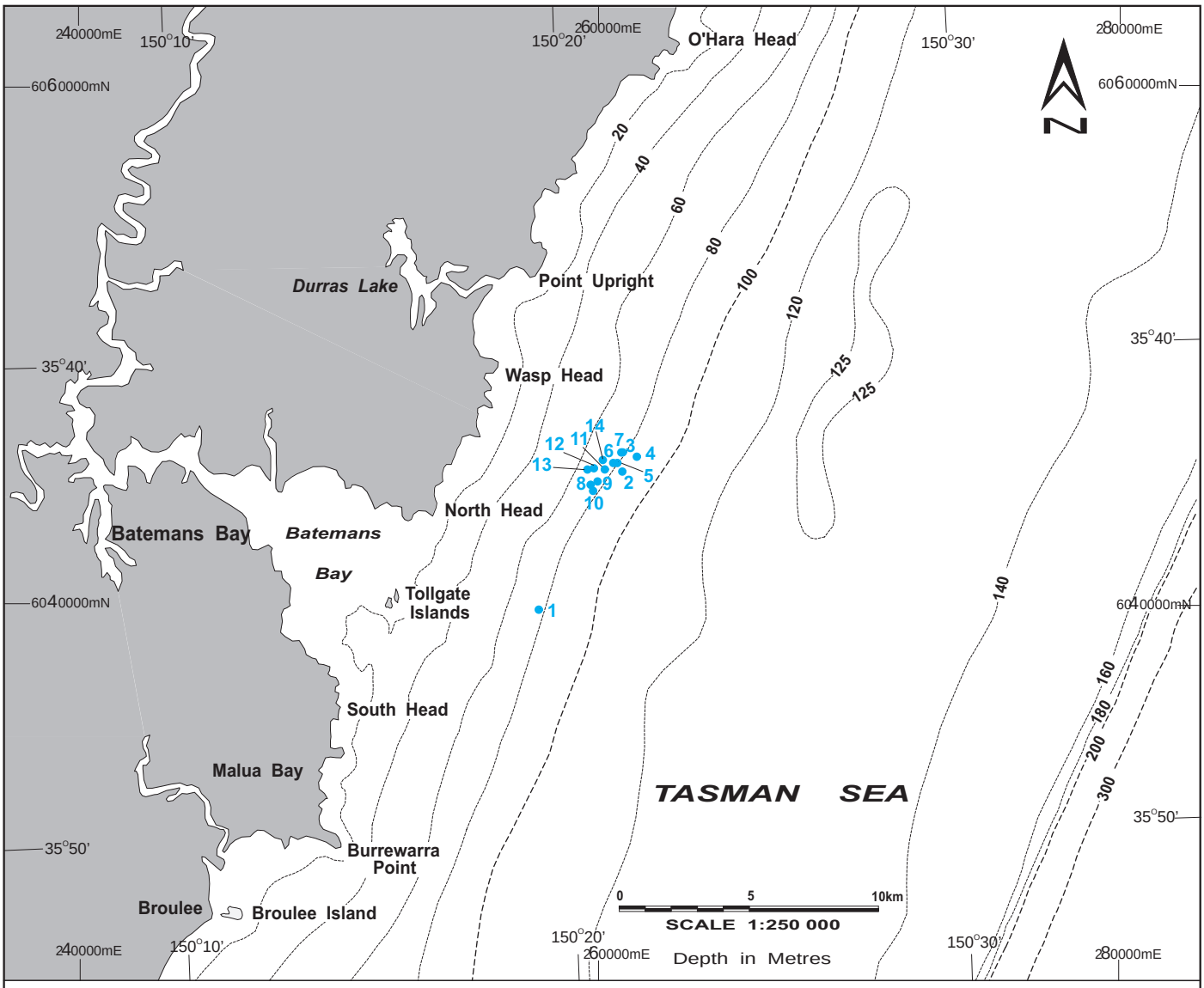
Manly Hydraulics Laboratory
NSW GOVERNMENT

PORT KEMBLA WAVERIDER BUOY
2016–2017 SIGNIFICANT WAVE HEIGHT TIME HISTORY

MHL Report 2576

Figure 5.10

DRAWING 2576-05-10.cdr



DEPLOYMENT LOCATION	LOCATION DETAILS				WATER DEPTH (m)	DEPLOYMENT PERIOD	
	Latitude (S)	Longitude (E)	MGA (Zone 56H) Easting	Northing		First Date	Last Date
1	35°45'19"	150°19'11"	257650	6039860	79	27-May-1986	02-Jun-1986
2	35°42'29"	150°21'25"	260880	6045200	75	02-Jun-1986	30-Sep-1987
3	35°42'05"	150°21'24"	260850	6045950	75	01-Oct-1987	29-Jun-1988
4	35°42'12"	150°21'47"	261430	6045750	84	30-Jun-1988	07-Feb-1989
5	35°42'18"	150°21'18"	260700	6045530	80	07-Feb-1989	19-Mar-1989
6	35°42'18"	150°21'12"	260550	6045530	73	11-Apr-1989	24-Oct-1989
7	35°42'05"	150°21'26"	260900	6045950	75	25-Oct-1989	09-Nov-1989
8	35°42'44"	150°20'35"	259650	6044700	73	22-Nov-1989	26-Apr-1990
9	35°42'40"	150°20'47"	259950	6044830	73	09-May-1990	19-Oct-1990
10	35°42'52"	150°20'39"	259750	6044450	73	13-Nov-1990	05-Jan-1997
11	35°42'26"	150°20'58"	260200	6045270	75	05-Jan-1997	28-Mar-1998
12	35°42'24"	150°20'41"	259780	6045320	73	29-Apr-1998	30-Jul-2004
13	35°42'26"	150°20'55"	260030	6045090	73	30-Jul-2004	18-Dec-2007
14	35°42'11"	150°20'38"	259680	6045740	73	25-Jan-2008	Present

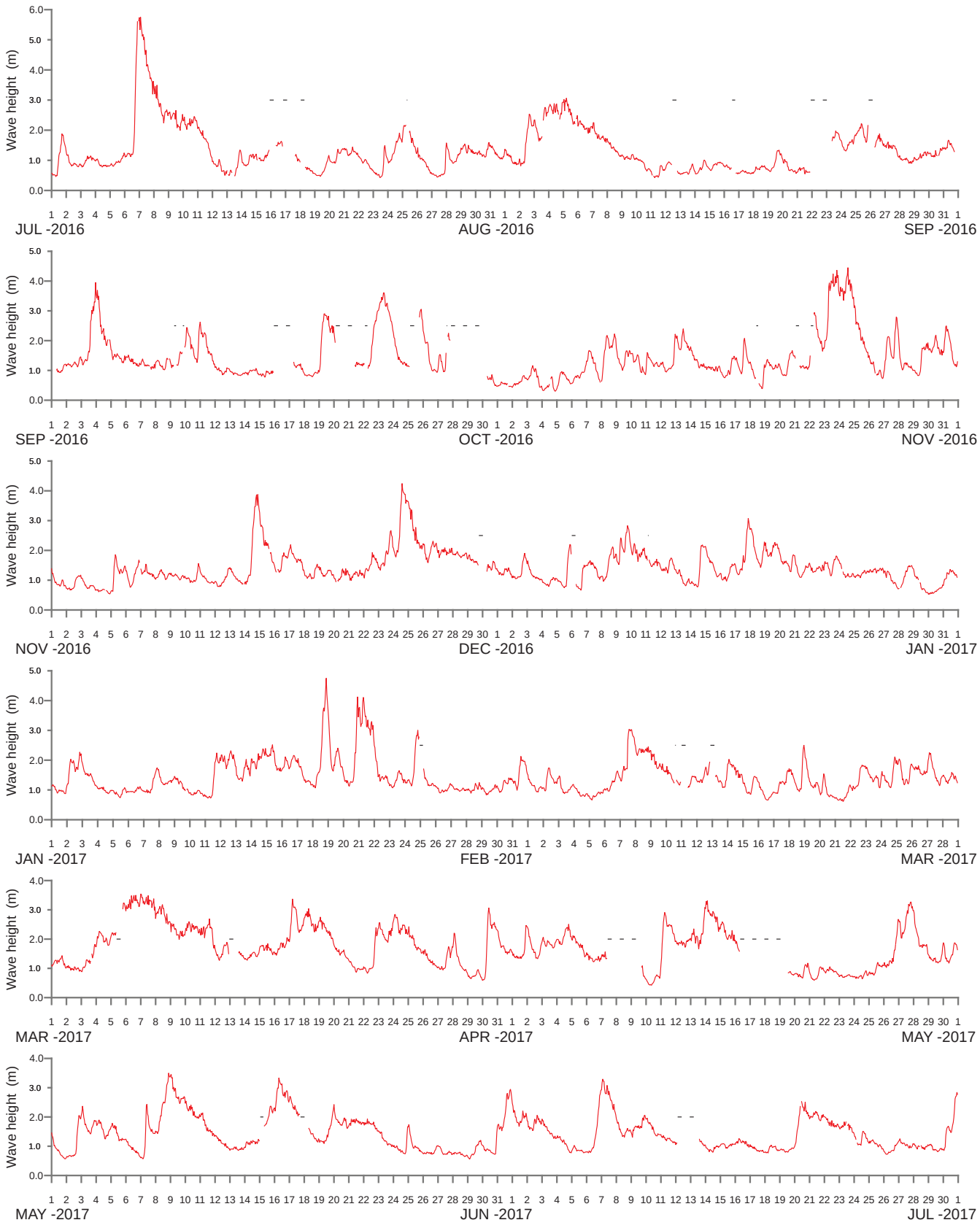
NSW GOVERNMENT Manly Hydraulics Laboratory

BATEMANS BAY WAVERIDER BUOY LOCATION HISTORY

MHL Report 2576

Figure 5.11

DRAWING 2576-05-11.cdr



Manly Hydraulics Laboratory

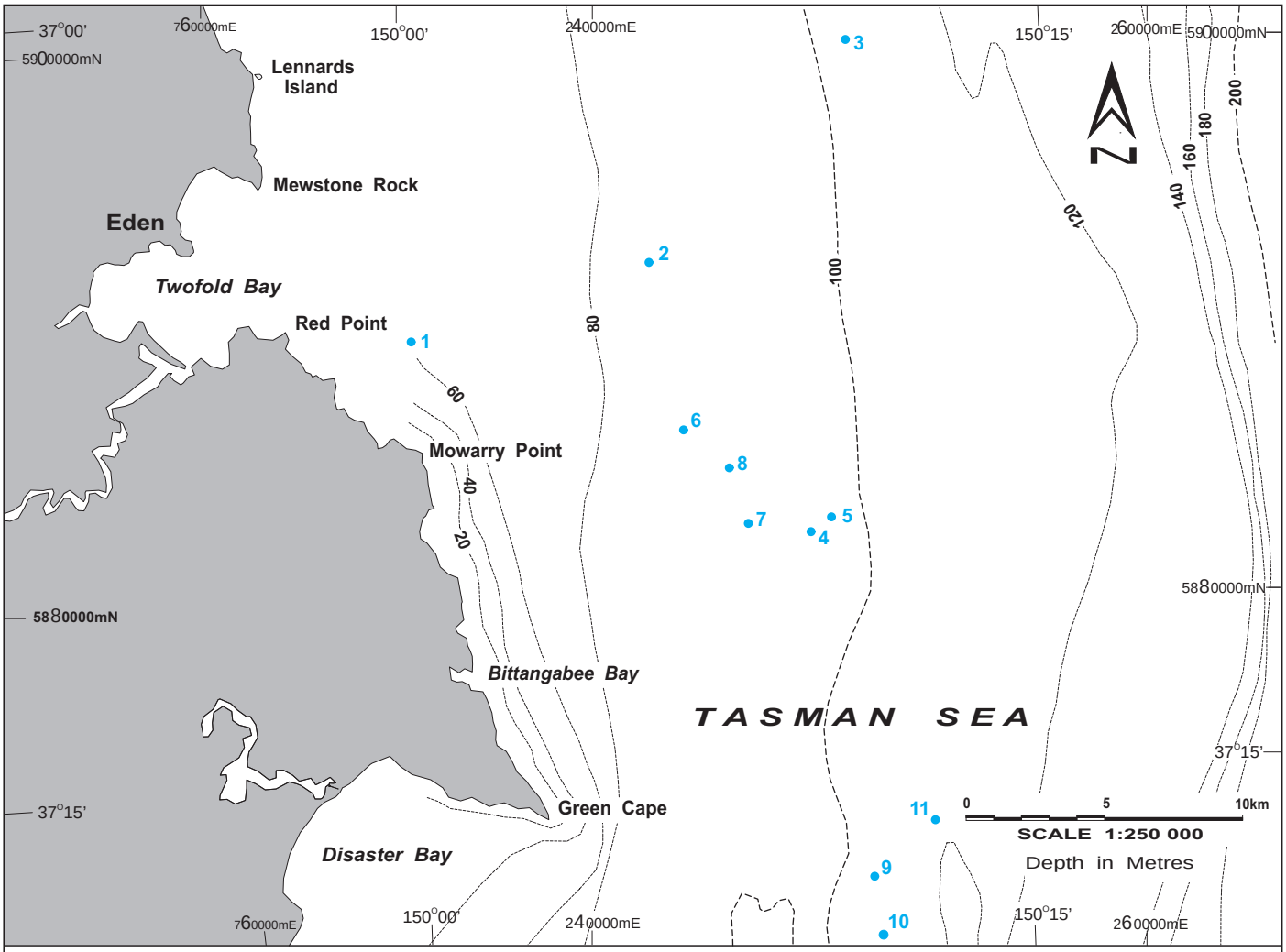
NSW GOVERNMENT

BATEMANS BAY WAVERIDER BUOY 2016–2017 SIGNIFICANT WAVE HEIGHT TIME HISTORY

MHL Report 2576

Figure 5.12

DRAWING 2576-05-12.cdr



DEPLOYMENT LOCATION	LOCATION DETAILS				WATER DEPTH (m)	DEPLOYMENT PERIOD	
	Latitude (S)	Longitude (E)	MGA (Zone 56H) Easting	Northing		First Date	Last Date
1	37°06'36"	150°00'00"	233420	5888700	55	08-Feb-1978	21-Sep-1983
2	37°05'12"	150°05'48"	241930	5891550	79	21-Sep-1983	22-Sep-1984
3	37°01'00"	150°10'42"	248960	5899540	104	10-Oct-1984	23-Oct-1984
4	37°10'30"	150°09'30"	247710	5881920	86	21-Mar-1985	15-Oct-1986
5	37°10'13"	150°10'01"	248450	5882450	95	15-Oct-1986	04-Feb-1987
6	37°08'28"	150°06'30"	243150	5885550	80	04-Feb-1987	10-Feb-1987
7	37°10'18"	150°08'00"	245480	5882220	90	23-Apr-1987	04-Feb-1988
8	37°09'12"	150°07'35"	244800	5884200	90	04-Feb-1988	07-Mar-1989
9	37°17'12"	150°10'48"	250000	5869580	110	07-Mar-1989	14-Sep-2000
10	37°18'06"	150°11'06"	250500	5866890	100	14-Sep-2000	05-Jul-2012
11	37°15'57"	150°11'36"	251120	5871940	100	20-Jul-2012	Present

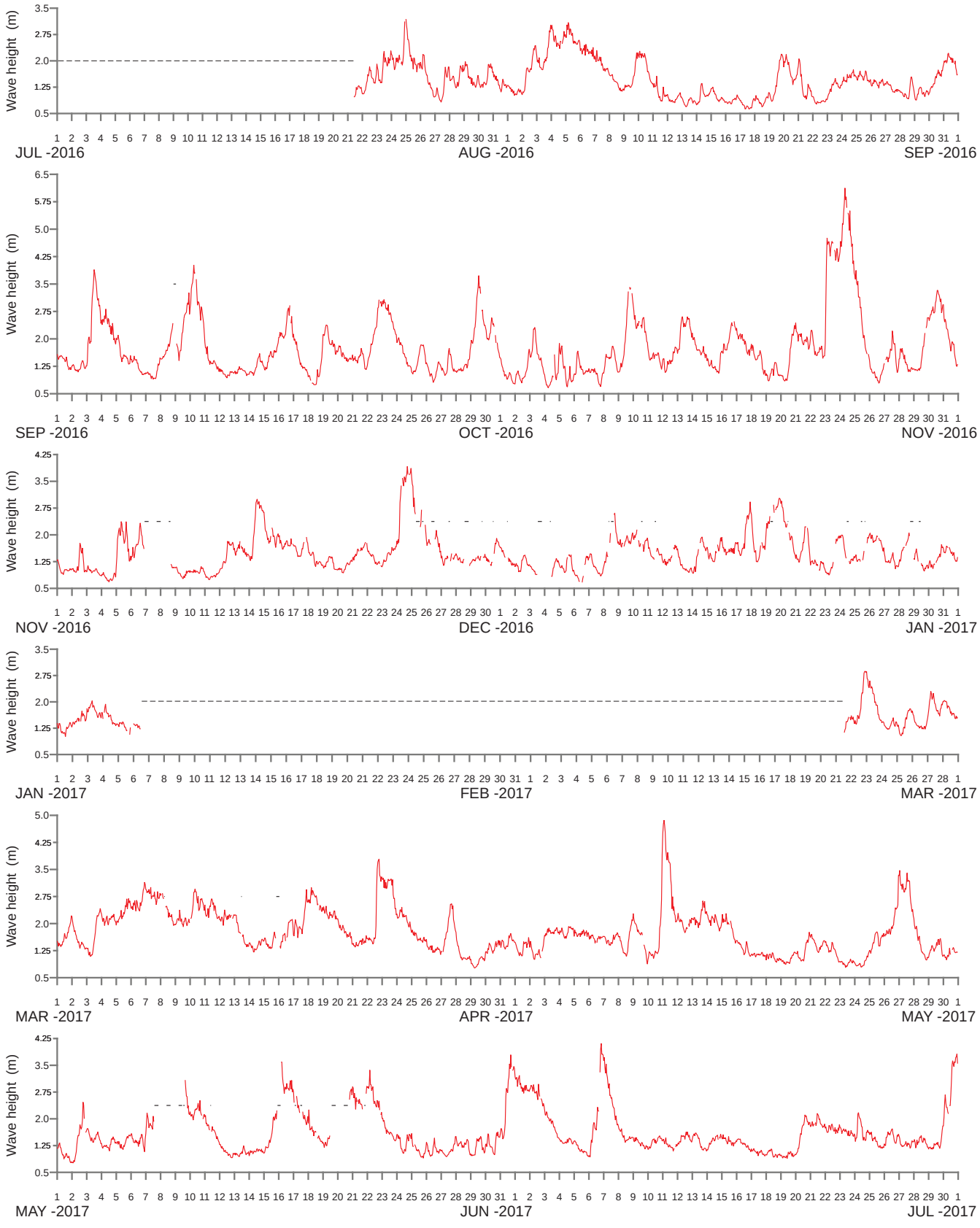
NSW GOVERNMENT Manly Hydraulics Laboratory

EDEN WAVERIDER BUOY LOCATION HISTORY

MHL Report 2576

Figure 5.13

DRAWING 2576-05-13.cdr



DATA LOSS

Manly Hydraulics Laboratory

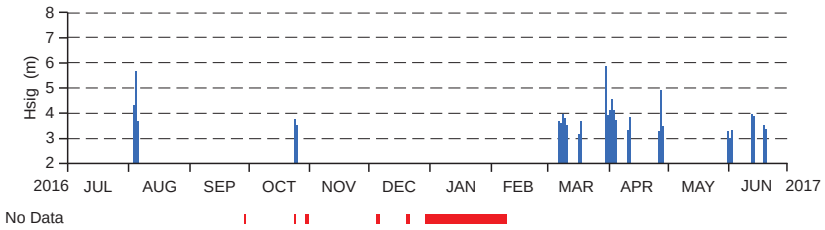
NSW GOVERNMENT

EDEN WAVERIDER BUOY
2016–2017 SIGNIFICANT WAVE HEIGHT TIME HISTORY

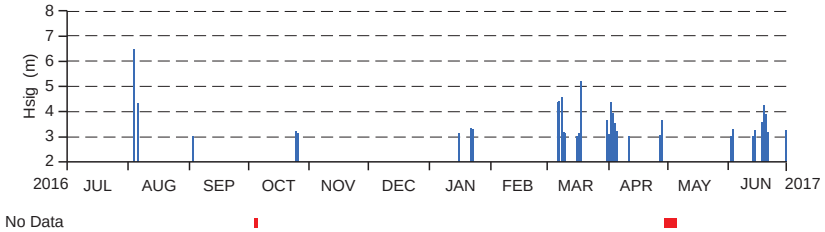
MHL Report 2576

Figure 5.14

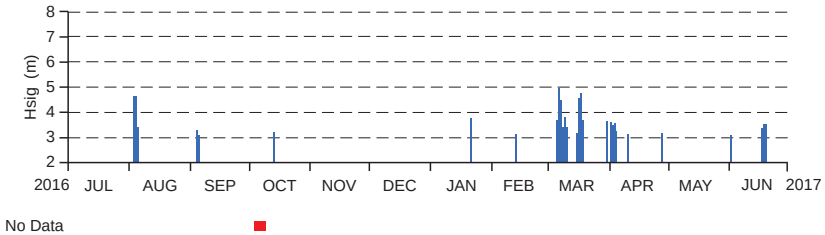
DRAWING 2576-05-14.cdr



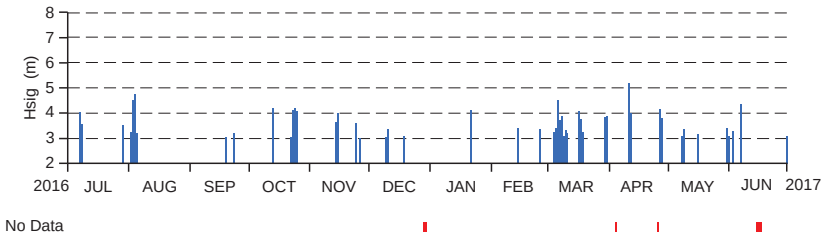
Byron Bay



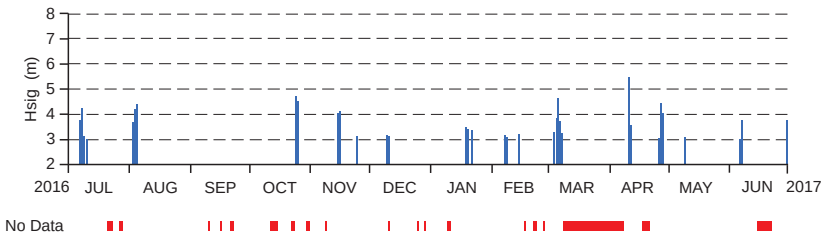
Coffs Harbour



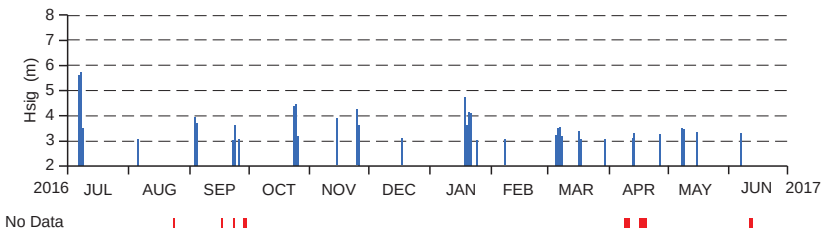
Crowdy Head



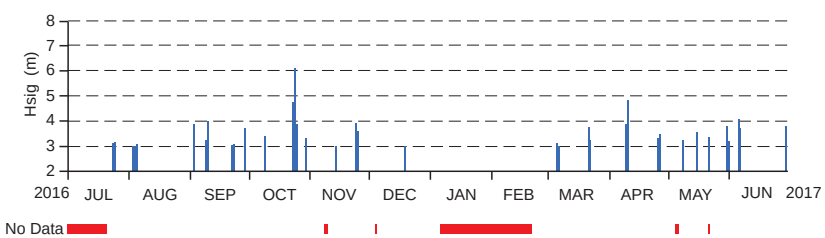
Sydney



Port Kembla



Batemans Bay



Eden

NSW GOVERNMENT Manly Hydraulics Laboratory

STORM HISTORY AND WAVERIDER SYSTEM DOWNTIME SUMMARY 2016–2017

MHL Report 2576

Figure 5.15

DRAWING 2576-05-15.cdr

6. Wave data capture and analysis

All analysed wave data from the offshore sites is archived on the Laboratory's central computer. This data set includes selected hand-analysed results for installations operational before 1978 that recorded data on strip chart. Analysed data for all sites is resident on hard disk, however, due to storage restrictions raw time series data is archived on an optical disk system. If required, raw wave data can be recovered from the optical disk system for further analysis.

6.1 Non-directional wave analysis

The first non-directional Waverider buoy was deployed by Manly Hydraulics Laboratory in February 1974 and initially recorded raw wave data traces on paper strip chart every six hours. In 1978 the introduction of the first electronic data loggers allowed more complete analysis but the record interval remained at six hours due to the limited memory capacity of these early loggers. In mid-1984 data logging and analysis was significantly enhanced with the introduction of the Manly Hydraulics Laboratory-developed programmable LSI-11 data logger. The LSI-11 data logger software was upgraded for the introduction of Directional Waverider buoys in March 1992. After over 20 years of service the LSI-11 system was phased out between October 2005 and December 2007 and was replaced with the current *MetOcean* PC data logging, processing and telemetry system.

The recorded 2048-second bursts (34 minutes) at each site are digitised at 1.28 Hz (0.78-second) intervals and the data is conditioned to remove erroneous data points. The data is then analysed using the standard zero crossing and spectral methods. This section briefly outlines the terminology associated with these two methods.

It should be noted that in addition to the offshore network the Laboratory undertakes site specific wave data capture programs associated with particular projects, such as breakwater design/construction, harbour design/construction, beach erosion studies, etc. A range of instruments can be used to obtain wave information.

In general, the following instruments/applications are employed:

- Directional Waverider buoys in deep or intermediate water depth to provide wave height, period and direction spectral information.
- Waverider buoys in deep or intermediate water depth to provide wave height, period and spectral information.
- Electromagnetic wave and tide monitoring systems (EWS) in shallow water to provide wave height, period, spectral and tidal information.
- From 1979 to 1989 Marsh McBirney and InterOcean S4 electromagnetic adaptive current meters were used to provide XY current information over the whole spectrum. The wave components are analysed and stored in a similar fashion to the Waverider and EWS data. Additionally, the current meters can provide wave direction information. When combined with an EWS or pressure sensor, estimates of the directional spectrum can be obtained.

- Teledyne RD Instruments Acoustic Doppler Current Profiler (ADCP) deployed on the seabed in shallow water to capture wave height, period and spectral information. The ADCP provides a comprehensive data set that can be processed to provide data on water level, wave conditions and current speed and direction through the water column above the instrument.

Site specific studies utilise the same software/hardware for record analysis as the offshore network and provide additional inshore information at specific sites. For this reason, a list of these study sites and their operational status has been included in Section 7.

6.1.1 Zero crossing analysis

A direct, repeatable and widely accepted method to extract representative statistics from the wave traces is the zero crossing method (Figure 6.1). For this method, a 'wave' is defined as the portion of record between two successive zero upcrossings. The waves are ranked (with their corresponding periods), and the following statistics computed:

H_{sig}	:	significant wave height = average height of the waves which comprise the top 33%
H_{10}	:	average height of the waves which comprise the top 10%
H_{max}	:	maximum wave height in a record
H_{rms}	:	root mean square wave height
H_{mean}	:	mean wave height
T_z	:	zero crossing period = mean period
T_{sig}	:	significant period = average period of the waves used to define H_{sig}
T_c	:	crest period = average time between successive crests (this involves a different definition of wave)

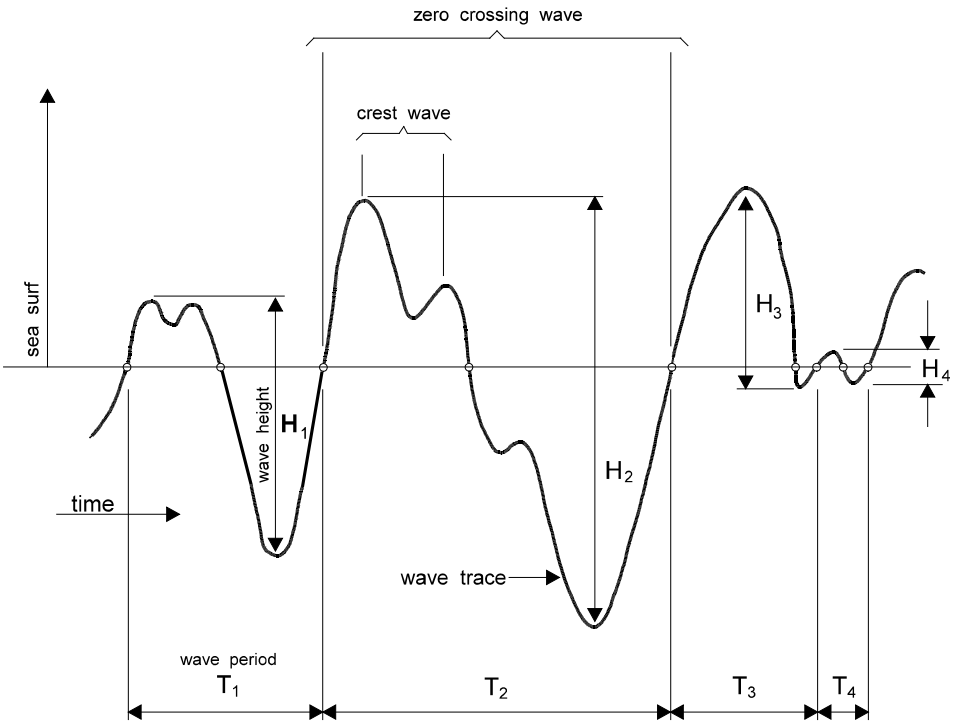


Figure 6.1 Zero crossing wave

6.1.2 Spectral analysis

The sea's motion at a point can be thought of as being composed of the sum of an infinite number of sine waves, each with its own amplitude (*a*), frequency (*f*) and phase (ϕ).

$$\eta(t) = \int_{o}^{oo} a\,(f)\,\sin\,[2\pi ft - \phi(f)]\,df$$

Spectral analysis using the Fast Fourier Transform technique provides estimates of the components. Rather than plotting the amplitudes, it is conventional to plot the energy density, E (effectively a^2/df).

For convenience, and because users are often interested in the shape of spectra, the values are scaled to give unity area.

The following statistics are computed from the spectrum:

T_{P1}	:	Period of highest peak
T_{P2}	:	Period of second highest peak
Y_{rms}	:	Root mean square surface vertical displacement

M_0, M_1, M_2, M_3 : Spectral moments - $M_n = \Sigma E f^n \Delta f$

These provide parameters describing the shape of the spectrum. Spectral moments can also be related statistically to the zero crossing parameters:

$$H_{rms} \approx 2\sqrt{2M_0} = 2\sqrt{2}Y_{rms}, \text{ where } M_0 = Y_{rms}^2$$

$$H_{sig} \approx 4\sqrt{M_0} = 4Y_{rms} = \sqrt{2}H_{rms}$$

$$H_{10} \approx 5.1\sqrt{M_0} = 5.1Y_{rms}$$

$$H_1 \approx 6.68\sqrt{M_0} = 6.68\ Y_{rms}$$

$$H_{mean} \approx 2.5\sqrt{M_0} = 2.5\ Y_{rms} = 0.886\ H_{rms}$$

An example of a spectral diagram is presented in Figure 6.2.

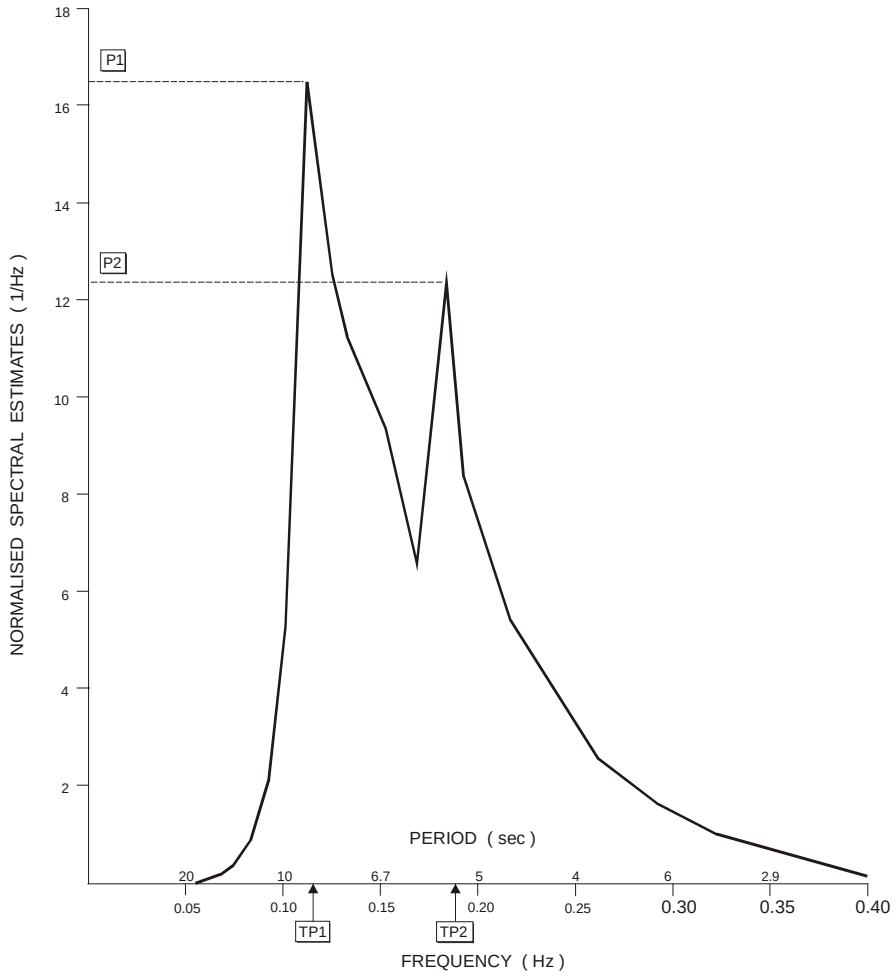


Figure 6.2 Spectral diagram

6.2 The Directional Waverider buoy

Manly Hydraulics Laboratory uses Directional Waverider buoys to monitor wave height, period and direction at the seven NSW offshore wave monitoring stations. The original Mark I version of the Directional Waverider buoy was introduced by Datawell in early 1990, followed by the Mark II buoy in mid-1995. The Mark III Directional Waverider buoy, introduced in the mid-2000s, represented a significant upgrade and included a GPS receiver to continuously report its location to the shore station enabling the buoy location to be tracked should it go adrift. Mark III buoys are used in the NSW Waverider buoy network.

The Directional Waverider buoy utilises a heave-pitch-roll sensor, two fixed 'X' and 'Y' accelerometers and a three axis fluxgate compass to measure both vertical and horizontal motion at a sample rate of 1.28 Hz (0.78 seconds). A single point mooring is used, with horizontal freedom ensured by the inclusion of a 30 m rubber shock cord in the mooring system. An on-board processor converts the buoy motion to three orthogonal (vertical, north-south, east-west) translation signals that are telemetered to the shore station. The directional spectrum is also routinely calculated by the buoy and transmitted to the receiving station for reformatting and storage prior to transfer to Manly Hydraulics Laboratory via the *MetOcean* email system.

Detailed information on the directional data analysis undertaken by the Directional Waverider buoy can be found in the Datawell Waverider Reference Manual, 2007.

7. Wave data index

Since 1974 wave data have been collected at over 40 locations along the NSW coast using a variety of wave motion sensors. This section includes a catalogue of all wave data stored on the Manly Hydraulics Laboratory central computer. Details of analysed wave data available are presented in three tables grouped according to the following categories:

- Table 7.1: Offshore stations – Waverider buoys deployed to provide deepwater wave data. The buoys are typically moored in a water depth of 80 m between 6 km and 12 km from the shoreline. At the buoy location the water is sufficiently deep that wave refraction, diffraction, shoaling and friction attenuation effects are minimal
- Table 7.2: Site specific stations – wave data collected by a variety of sensors in intermediate or shallow water. These stations gather wave data for particular projects such as breakwater design/construction, harbour design/construction, beach erosion studies, etc. The wave characteristics at these inshore locations may be significantly affected by refraction, diffraction, shoaling and friction attenuation
- Table 7.3: Long wave stations – water level data collected at selected EWS stations are filtered and analysed to provide long wave statistics. Long waves have periods that range from 30 seconds to several minutes and are often associated with storm wave activity off the NSW coast.

Due to limited storage capacity on the computer raw time series wave data is archived on optical disk. Table 7.4 provides an index of raw data stored on optical disk. Prior to mid-2006, at most sites raw data was normally saved twice per day at 0900 and 2100 hours and every second hour during storm events (H_{sig} greater than 3 m for offshore sites). Since 2006, with the introduction of the *MetOcean* system, raw data is archived hourly for all wave data collection stations.

It should be noted that raw data is not available for all sites or before January 1981.

Table 7.1 Analysed wave data at Manly Hydraulics Laboratory: offshore stations – June 2017

Wave data site	Instrument	MGA location (Zone 56)		Water depth (m)	Data available		Record length (years)	Data capture (%)
		Easting	Northing		First date	Last date		
Byron Bay	Waverider buoy	572 700	6 822 180	72	14-Oct-1976	26-Oct-1999	40.71	74.5
Byron Bay	Directional Waverider buoy	568 270	6 806 650	62	26-Oct-1999	Present		
Coffs Harbour	Waverider buoy	525 920	6 641 140	72	26-May-1976	13-Feb-2012	41.12	85.5
Coffs Harbour	Directional Waverider buoy	524 880	6 639 880	72	14-Feb-2012	Present		
Crowdy Head	Waverider buoy	486 720	6 478 910	79	10-Oct-1985	19-Aug-2011	31.72	86.8
Crowdy Head	Directional Waverider buoy	486 720	6 478 910	79	19-Aug-2011	Present		
Sydney	Waverider buoy	353 490	6 261 200	85	17-Jul-1987	04-Oct-2000	13.23	92.2
Sydney Directional	Directional Waverider buoy	352 940	6 262 340	92	03-Mar-1992	Present	25.33	86.9
Port Kembla	Waverider buoy	318 720	6 183 460	80	07-Feb-1974	14-May-2012	43.42	82.4
Port Kembla	Directional Waverider buoy	318 310	6 183 740	80	20-Jun-2012	Present		
Batemans Bay	Waverider buoy	259 780	6 045 320	73	27-May-1986	23-Feb-2001	31.11	90.0
Batemans Bay	Directional Waverider buoy	259 080	6 045 190	73	23-Feb-2001	Present		
Eden	Waverider buoy	250 500	5 866 890	100	08-Feb-1978	16-Dec-2011	39.39	83.1
Eden	Directional Waverider buoy	251 120	5 871 940	100	16-Dec-2011	Present		

Table 7.2 Analysed wave data at Manly Hydraulics Laboratory: site specific stations – June 2017

Wave data site	Instrument	MGA location (Zone 56)		Water depth (m)	Data available		Record length (years)	Data capture (%)
		Easting	Northing		First date	Last date		
Tweed River	EWS	553 860	6 883 725	4	20-Jan-1995	27-Nov-2008	13.86	68.4
Tweed Heads Inshore	Waverider buoy	555 294	6 883 017	13	21-Apr-1989	08-Nov-1989	0.55	97.0
Tweed Heads	Marsh McBirney	555 294	6 883 017	13	09-Jun-1988	10-Oct-1989	1.34	61.6
Cook Island	Marsh McBirney / S4	556 003	6 881 182	12	09-Jun-1988	25-Oct-1989	1.38	40.8
Fingal Head	Marsh McBirney / S4	556 079	6 879 564	12	09-Jun-1988	25-Oct-1989	1.38	30.7
Coffs Harbour Entrance	Marsh McBirney	514 665	6 646 863	9	04-Dec-1986	31-Oct-1987	0.91	52.9
Coffs Harbour Jetty	EWS	513 840	6 647 148	7	05-Nov-1986	15-Jan-1996	9.20	83.7
Coffs Harbour Jetty MMcB	Marsh McBirney	513 840	6 647 148	7	04-Dec-1986	20-Jan-1987	0.13	97.2
Coffs Harbour Boat Ramp	Marsh McBirney	513 674	6 646 699	6	21-Jan-1987	08-Mar-1987	0.13	90.6
Coffs Harbour Quarry	Marsh McBirney	514 163	6 646 618	6	10-Mar-1987	27-Apr-1987	0.13	84.1
Muttonbird Island West	Marsh McBirney	514 110	6 647 040	6	29-Apr-1987	17-Jun-1987	0.13	81.6
Coffs Inner Hbr Entrance	Marsh McBirney	513 790	6 647 313	4	19-Jun-1987	04-Aug-1987	0.13	89.2
Muttonbird Island East	Marsh McBirney	514 790	6 647 105	11	14-Aug-1987	06-Oct-1987	0.15	62.1
Muttonbird Island South	Marsh McBirney	514 415	6 647 000	7	07-Oct-1987	31-Oct-1987	0.07	96.0
Coffs Harbour Central	Marsh McBirney	513 927	6 646 790	8	05-Nov-1987	25-Nov-1987	0.06	96.4
Coffs Inner Harbour	EWS	513 920	6 647 470	4	16-Jan-1996	08-Oct-2011	15.74	83.8
Crowdy Head Harbour	EWS	476 318	6 477 138	2	07-Nov-1986	16-Jul-2012	25.71	75.5
Jimmys Beach	EWS	421 665	6 383 610	3	16-Dec-1983	08-Oct-1985	1.82	86.0
Nelson Bay	EWS	419 720	6 379 447	6	20-Jan-1981	18-Jun-1986	4.92	36.1
Nelson Bay West Point	EWS	419 470	6 379 465	5	19-Jun-1986	20-Apr-1988	1.84	87.6
Swansea	EWS	375 079	6 338 043	2	17-Dec-1987	12-Apr-1991	3.32	98.6
Wamberal Beach	Direction Waverider	356 089	6 299 724	11	05-Aug-2011	16-Mar-2012	0.61	92.7
Broken Bay	Waverider buoy	346 190	6 285 235	24	30-Jan-1981	02-Jun-1983	2.34	53.1
Palm Beach	Marsh McBirney	345 650	6 281 755	24	19-Jun-1981	14-Sep-1982	1.24	41.1
Broken Bay Current	Marsh McBirney	346 190	6 284 795	24	23-Nov-1979	15-Feb-1983	3.23	71.7
Mackerel Beach	EWS	342 270	6 281 775	2	17-Aug-1988	15-Oct-1989	1.16	97.1
Narrabeen Beach	Direction Waverider	342 875	6 267 444	10	27-Jul-2011	14-Nov-2011	0.30	96.4
Long Reef	Waverider buoy	344 749	6 266 181	21	27-Jul-2011	14-Nov-2011	0.30	98.9
Melrose Park	EWS	321 365	6 255 975	2	24-Mar-1988	20-Jul-1988	0.32	81.7
Chiswick	EWS	327 650	6 253 076	2	28-Mar-1988	20-Jul-1988	0.31	74.6
Port Hacking Seaward	EWS	328 830	6 227 575	3	06-Sep-1983	04-Jan-2014	30.33	77.8
Deeban Spit	EWS	327 850	6 227 474	2	15-Sep-1983	03-Oct-1986	3.05	51.4
Port Hacking S'ward MMcB	Marsh McBirney	328 830	6 227 575	3	06-Sep-1983	17-Nov-1986	3.20	56.6
Deeban Spit MMcB	Marsh McBirney	327 850	6 227 474	2	06-Sep-1983	28-May-1985	1.73	60.5
Burraneer Point MMcB	Marsh McBirney	327 763	6 227 931	6	06-Sep-1983	16-Dec-1985	2.28	53.8
Port Kembla Inshore	Waverider buoy	307 990	6 184 970	18	31-May-1978	26-Jul-1982	4.16	72.3
Jervis Bay North	EWS	287 850	6 120 050	6	11-Nov-1981	03-Jul-1989	7.65	62.4
Jervis Bay South	EWS	288 500	6 118 800	8	01-Sep-1981	18-Oct-1983	2.13	35.4
Batemans Bay Inshore	EWS	247 792	6 043 097	7	26-Feb-1987	08-Dec-1990	3.78	94.1
Eden Inshore *	Waverider buoy	758 230	5 892 820	9	24-Nov-1984	11-May-1987	2.46	75.8
Eden Harbour *	EWS	758 324	5 892 999	4	24-Nov-1984	13-Nov-2012	27.97	85.1

* Location is relative to origin of Zone 55

Table 7.3 Analysed wave data at Manly Hydraulics Laboratory: long wave stations – June 2017

Wave data site	Instrument	MGA location (Zone 56)		Water depth (m)	Data available		Record length (years)	Data capture (%)
		Easting	Northing		First date	Last date		
Tweed River	EWS	553 860	6 883 725	4	20-Jan-1995	02-May-2005	10.29	78.8
Coffs Harbour Jetty	EWS	513 840	6 647 148	7	13-Jul-1987	15-Jan-1996	8.52	86.6
Coffs Inner Harbour	EWS	513 920	6 647 470	4	16-Jan-1996	04-Apr-2006	10.22	87.5
Crowdy Head Harbour	EWS	476 318	6 477 138	2	24-Jul-1987	07-Jan-2004	16.47	83.9
Swansea	EWS	375 079	6 338 043	2	09-Sep-1988	12-Apr-1991	2.59	98.3
Mackerel Beach	EWS	342 270	6 281 775	2	17-Aug-1988	15-Oct-1989	1.16	96.4
Port Hacking	EWS	328 830	6 227 575	3	20-Nov-1987	13-Apr-2004	16.41	87.6
Jervis Bay North	EWS	287 850	6 120 050	6	30-Jul-1987	03-Jul-1989	1.93	87.0
Batemans Bay	EWS	247 792	6 043 097	7	26-Aug-1987	08-Dec-1990	3.29	95.3
Eden Harbour *	EWS	758 324	5 892 999	4	28-Jul-1987	28-Feb-2006	18.60	90.4

* Location is relative to origin of Zone 55

Table 7.4 Raw wave data at Manly Hydraulics Laboratory: time series data – June 2017

Wave data site	Instrument	Site category	Available analysed data		Available raw data	
			First data	Last date	First date	Last date
Tweed River	EWS	Inshore	20-Jan-1995	27-Nov-2008	20-Jan-1995	27-Nov-2008
Tweed Heads Inshore	Waverider buoy	Inshore	21-Apr-1989	08-Nov-1989	21-Apr-1989	08-Nov-1989
Byron Bay	Waverider buoy	Offshore	14-Oct-1976	26-Oct-1999	12-Aug-1983	26-Oct-1999
Byron Bay	Direct'n Waverider	Offshore	26-Oct-1999	Present	26-Oct-1999	Present
Coffs Harbour	Waverider buoy	Offshore	26-May-1976	13-Feb-2012	29-Jul-1983	13-Feb-2012
Coffs Harbour	Direct'n Waverider	Offshore	14-Feb-2012	Present	14-Feb-2012	Present
Coffs Harbour Jetty	EWS	Inshore	05-Nov-1986	15-Jan-1996	05-Nov-1986	15-Jan-1996
Coffs Inner Harbour	EWS	Inshore	16-Jan-1996	08-Oct-2011	16-Jan-1996	08-Oct-2011
Crowdy Head	Waverider buoy	Offshore	10-Oct-1985	19-Aug-2011	10-Oct-1985	19-Aug-2011
Crowdy Head	Direct'n Waverider	Offshore	19-Aug-2011	Present	19-Aug-2011	Present
Crowdy Head Harbour	EWS	Inshore	07-Nov-1986	16-Jul-2012	07-Nov-1986	16-Jul-2012
Jimmys Beach	EWS	Inshore	16-Dec-1983	08-Dec-1985	16-Dec-1983	19-Sep-1985
Nelson Bay	EWS	Inshore	20-Jan-1981	18-Jun-1986	20-Jan-1981	18-Jun-1986
Nelson Bay West Point	EWS	Inshore	19-Jun-1986	20-Apr-1988	19-Jun-1986	20-Apr-1988
Swansea	EWS	Inshore	17-Dec-1987	12-Apr-1991	17-Dec-1987	11-Apr-1991
Wamberal Beach	Direct'n Waverider	Inshore	05-Aug-2011	16-Mar-2012	05-Aug-2011	16-Mar-2012
Mackerel Beach	EWS	Inshore	17-Aug-1988	15-Oct-1989	17-Aug-1988	14-Oct-1989
Narrabeen Beach	Direct'n Waverider	Inshore	27-Jul-2011	14-Nov-2011	27-Jul-2011	14-Nov-2011
Long Reef	Waverider buoy	Inshore	27-Jul-2011	14-Nov-2011	27-Jul-2011	14-Nov-2011
Sydney	Waverider buoy	Offshore	17-Jul-1987	04-Oct-2000	17-Jul-1987	04-Oct-2000
Sydney Directional	Direct'n Waverider	Offshore	03-Mar-1992	Present	03-Mar-1992	Present
Melrose Park (Parramatta R)	EWS	River	24-Mar-1988	20-Jul-1988	24-Mar-1988	20-Jul-1988
Chiswick (Parramatta River)	EWS	River	28-Mar-1988	20-Jul-1988	28-Mar-1988	20-Jul-1988
Port Hacking Seaward	EWS	Inshore	06-Sep-1983	04-Jan-2014	06-Sep-1983	04-Jan-2014
Deeban Spit	EWS	Inshore	15-Sep-1983	03-Oct-1986	15-Sep-1983	03-Oct-1986
Port Hacking Seaward MMcB	Marsh McBirney	Inshore	06-Sep-1983	17-Nov-1986	06-Sep-1983	17-Sep-1986
Deeban Spit MMcB	Marsh McBirney	Inshore	06-Sep-1983	28-May-1985	06-Sep-1983	27-May-1985
Burraneer Point MMcB	Marsh McBirney	Inshore	06-Sep-1983	16-Dec-1985	06-Sep-1983	04-Sep-1985
Port Kembla	Waverider buoy	Offshore	07-Feb-1974	14-May-2012	31-Jul-1983	14-May-2012
Port Kembla	Direct'n Waverider	Offshore	20-Jun-2012	Present	20-Jun-2012	Present
Jervis Bay North	EWS	Inshore	11-Nov-1981	03-Jul-1989	27-Dec-1982	03-Jul-1989
Jervis Bay South	EWS	Inshore	01-Sep-1981	18-Oct-1983	04-Jan-1983	18-Oct-1983
Batemans Bay	Waverider buoy	Offshore	27-May-1986	23-Feb-2001	27-May-1986	23-Feb-2001
Batemans Bay	Direct'n Waverider	Offshore	23-Feb-2001	Present	23-Feb-2001	Present
Batemans Bay Inshore	EWS	Inshore	26-Feb-1987	08-Dec-1990	26-Feb-1987	08-Dec-1990
Eden	Waverider buoy	Offshore	08-Feb-1978	16-Dec-2011	26-Jul-1983	16-Dec-2011
Eden	Direct'n Waverider	Offshore	16-Dec-2011	Present	16-Dec-2011	Present
Eden Inshore	Waverider buoy	Inshore	24-Nov-1984	11-May-1987	24-Nov-1984	11-May-1987
Eden Harbour	EWS	Inshore	24-Nov-1984	13-Nov-2012	24-Nov-1984	13-Nov-2012

8. Air pressure program summary 2016–2017

8.1 Data capture

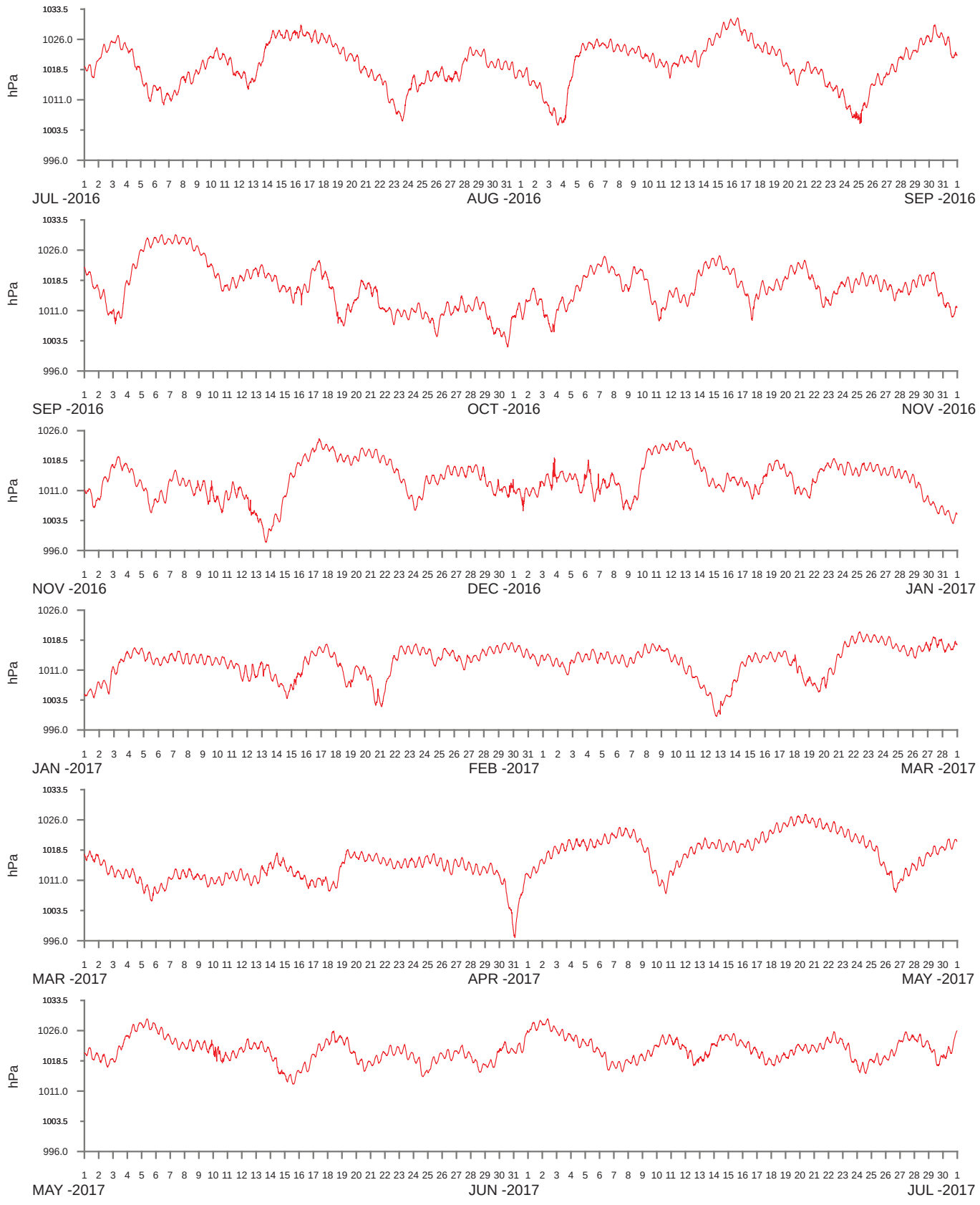
Since the introduction of the Vaisala digital barometers during 1999–2000, data recovery from the New South Wales coastal barometer network has been excellent. As shown in Table 8.1, during the 2016–2017 year all eight stations achieved 100 percent data recovery.

Table 8.1 New South Wales air pressure: 2016–2017 data capture

Waverider site	Data capture (%)												Total year
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
Tweed Heads	100	100	100	100	100	100	100	100	100	100	100	100	100
Yamba	100	100	100	100	100	100	100	100	100	100	100	100	100
Port Macquarie	100	100	100	100	100	100	100	100	100	100	100	100	100
Newcastle	100	100	100	100	100	100	100	100	100	100	100	100	100
Sydney	100	100	100	100	100	100	100	100	100	100	100	100	100
Jervis Bay	100	100	100	100	100	100	100	100	100	100	100	100	100
Tuross Heads	100	100	100	100	100	100	100	100	100	100	100	100	100
Eden	100	100	100	100	100	100	100	100	100	100	100	100	100
Total Months	100	100	100	100	100	100	100	100	100	100	100	100	100

8.2 Internet access

Air pressure data is routinely telemetered to the Laboratory from the eight barometric stations throughout each day. Access to a seven-day time history plot of air pressure is available via the near-real time data link at www.mhl.nsw.gov.au/data/realtime/barometric/



BAROMETRIC PRESSURE REFERENCED TO MEAN SEA LEVEL

---------- DATA LOSS

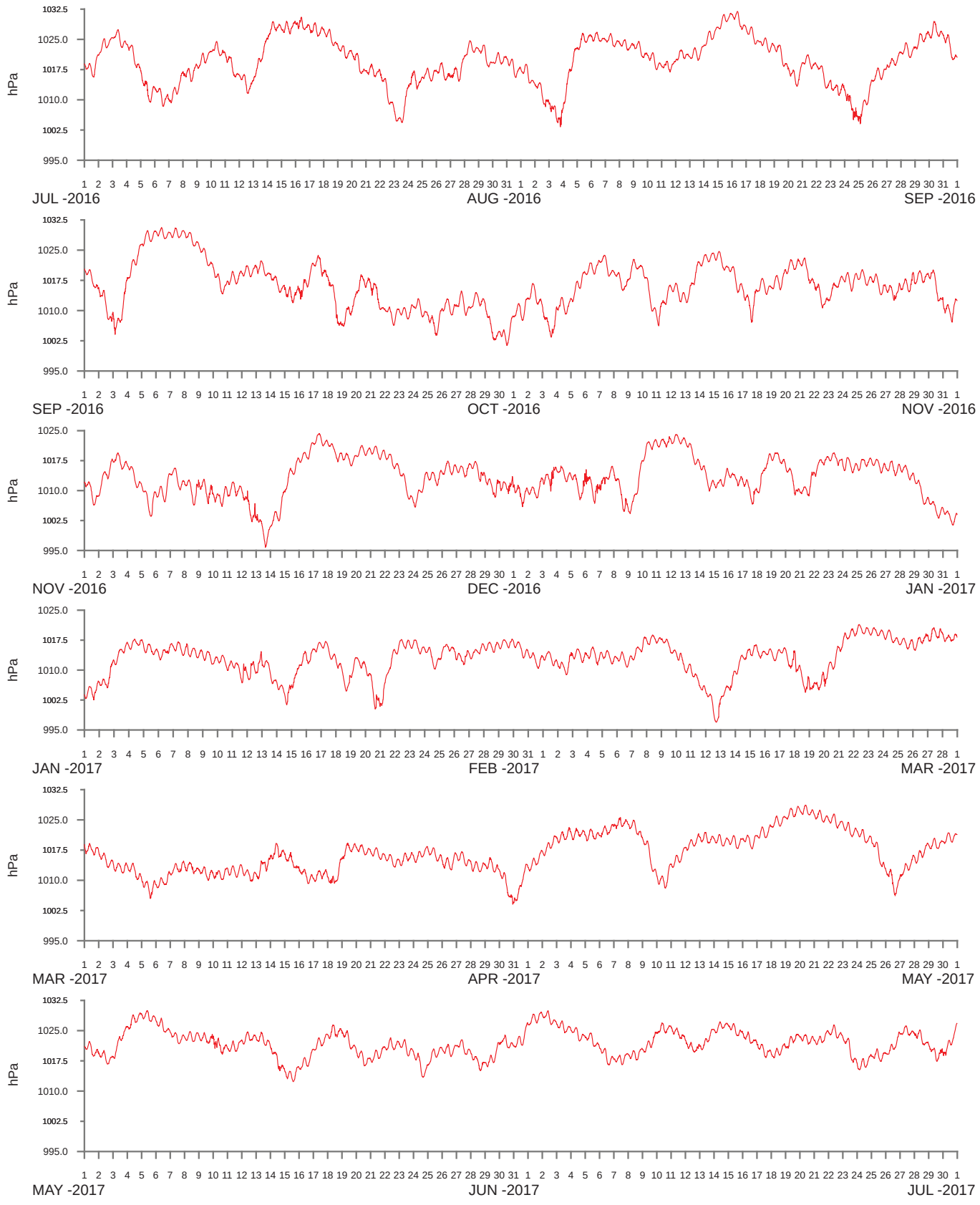
NSW GOVERNMENT Manly Hydraulics Laboratory

TWEED HEADS BAROMETER
2016–2017 AIR PRESSURE

MHL Report 2576

Figure 8.1

DRAWING 2576-08-01.cdr



BAROMETRIC PRESSURE REFERENCED TO MEAN SEA LEVEL

---------- DATA LOSS

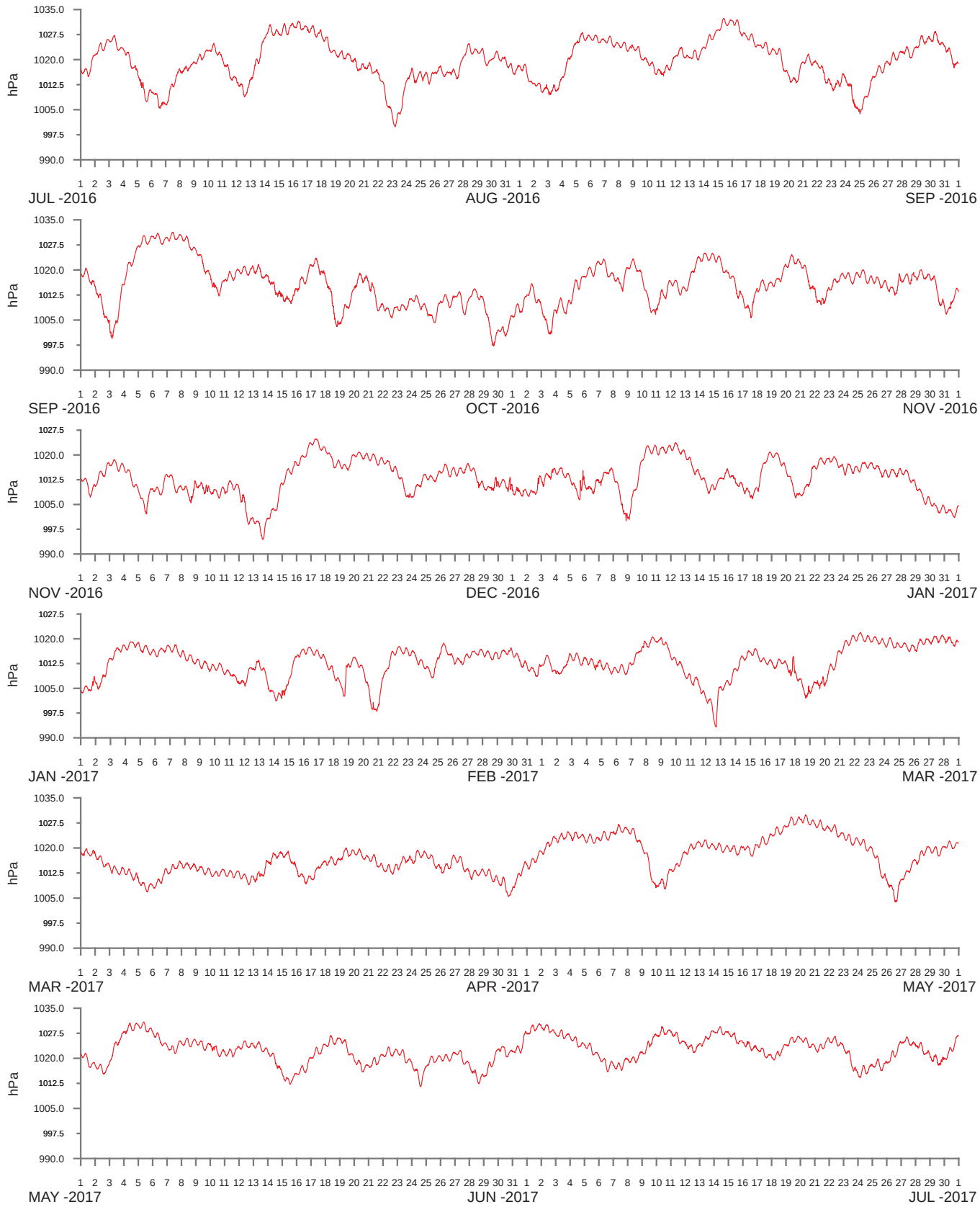
NSW GOVERNMENT Manly Hydraulics Laboratory

YAMBA BAROMETER
2016–2017 AIR PRESSURE

MHL Report 2576

Figure 8.2

DRAWING 2576-08-02.cdr



BAROMETRIC PRESSURE REFERENCED TO MEAN SEA LEVEL

DATA LOSS

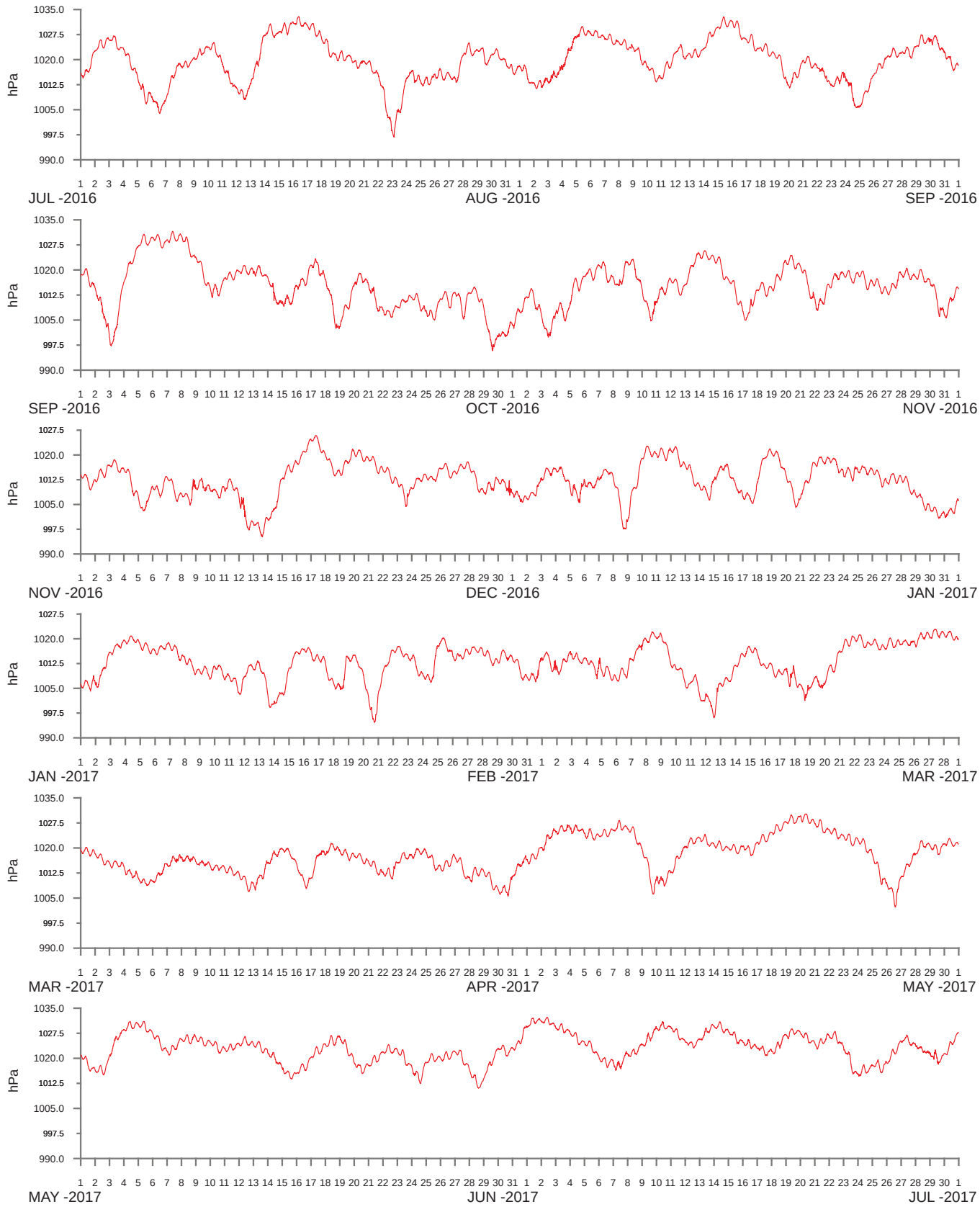
NSW GOVERNMENT Manly Hydraulics Laboratory

PORT MACQUARIE BAROMETER 2016–2017 AIR PRESSURE

MHL Report 2576

Figure 8.3

DRAWING 2576-08-03.cdr



BAROMETRIC PRESSURE REFERENCED TO MEAN SEA LEVEL

---------- DATA LOSS

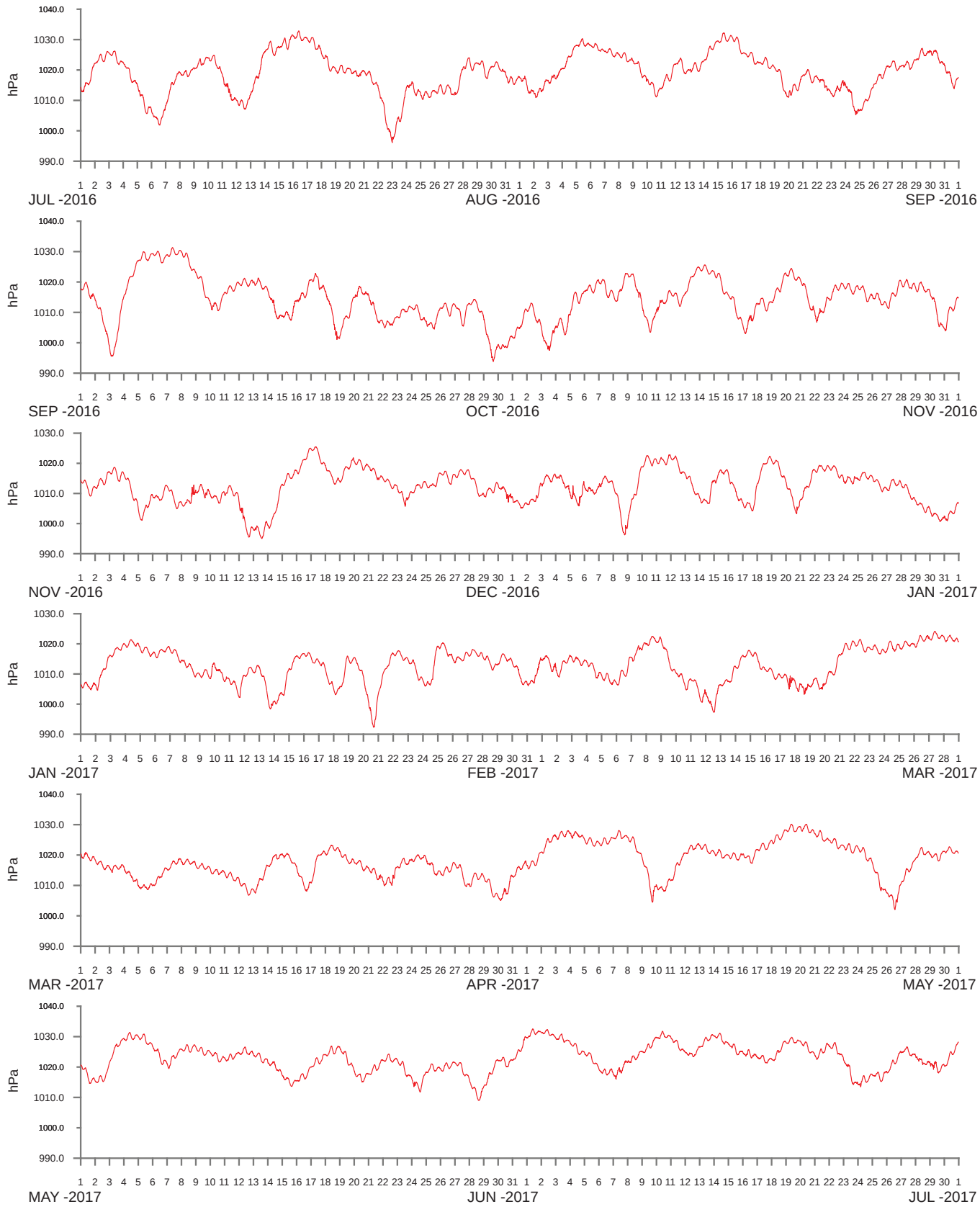
NSW GOVERNMENT Manly Hydraulics Laboratory

NEWCASTLE BAROMETER
2016–2017 AIR PRESSURE

MHL Report 2576

Figure 8.4

DRAWING 2576-08-04.cdr



BAROMETRIC PRESSURE REFERENCED TO MEAN SEA LEVEL

DATA LOSS

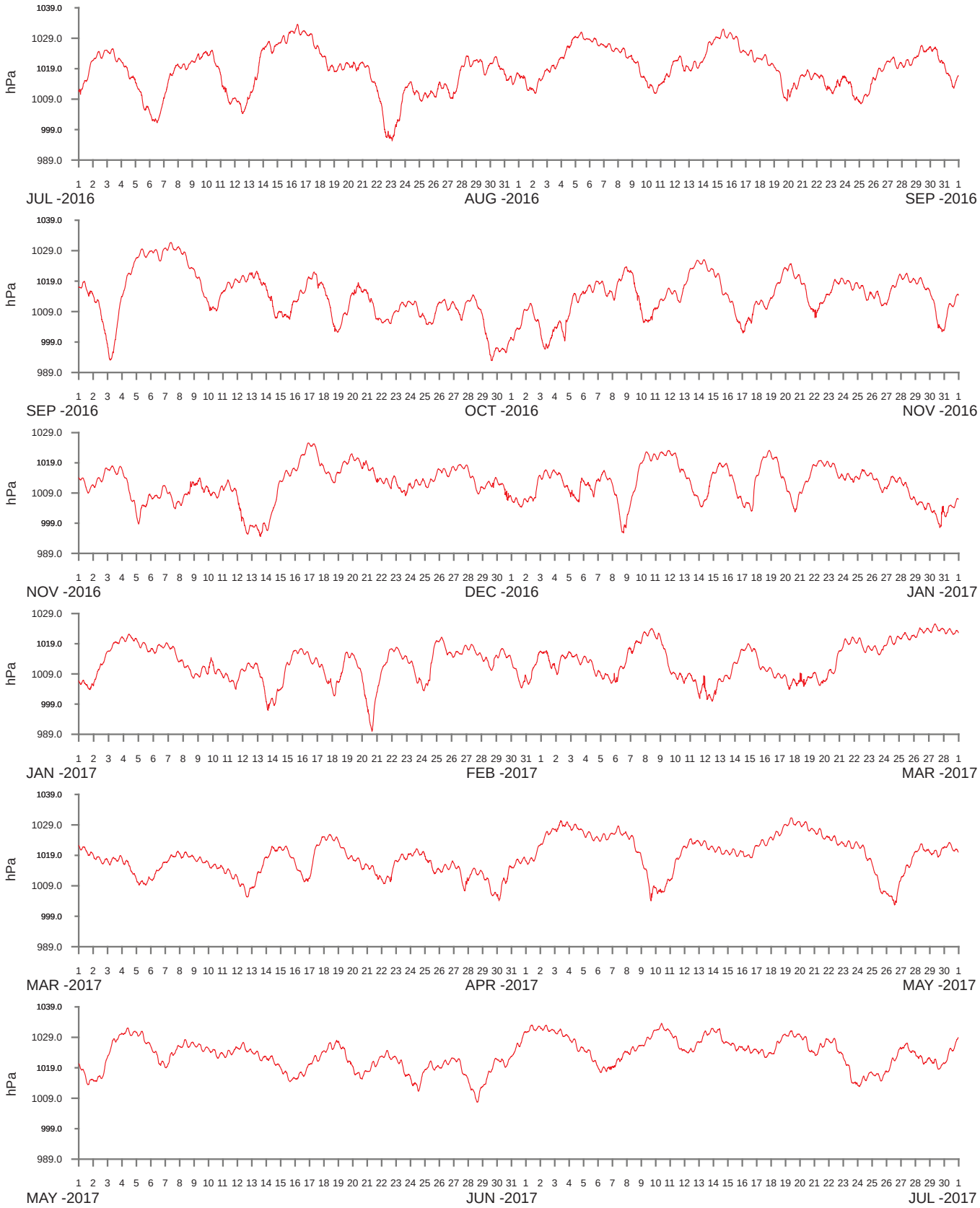
NSW GOVERNMENT Manly Hydraulics Laboratory

SYDNEY BAROMETER
2016–2017 AIR PRESSURE

MHL Report 2576

Figure 8.5

DRAWING 2576-08-05.cdr



BAROMETRIC PRESSURE REFERENCED TO MEAN SEA LEVEL

DATA LOSS

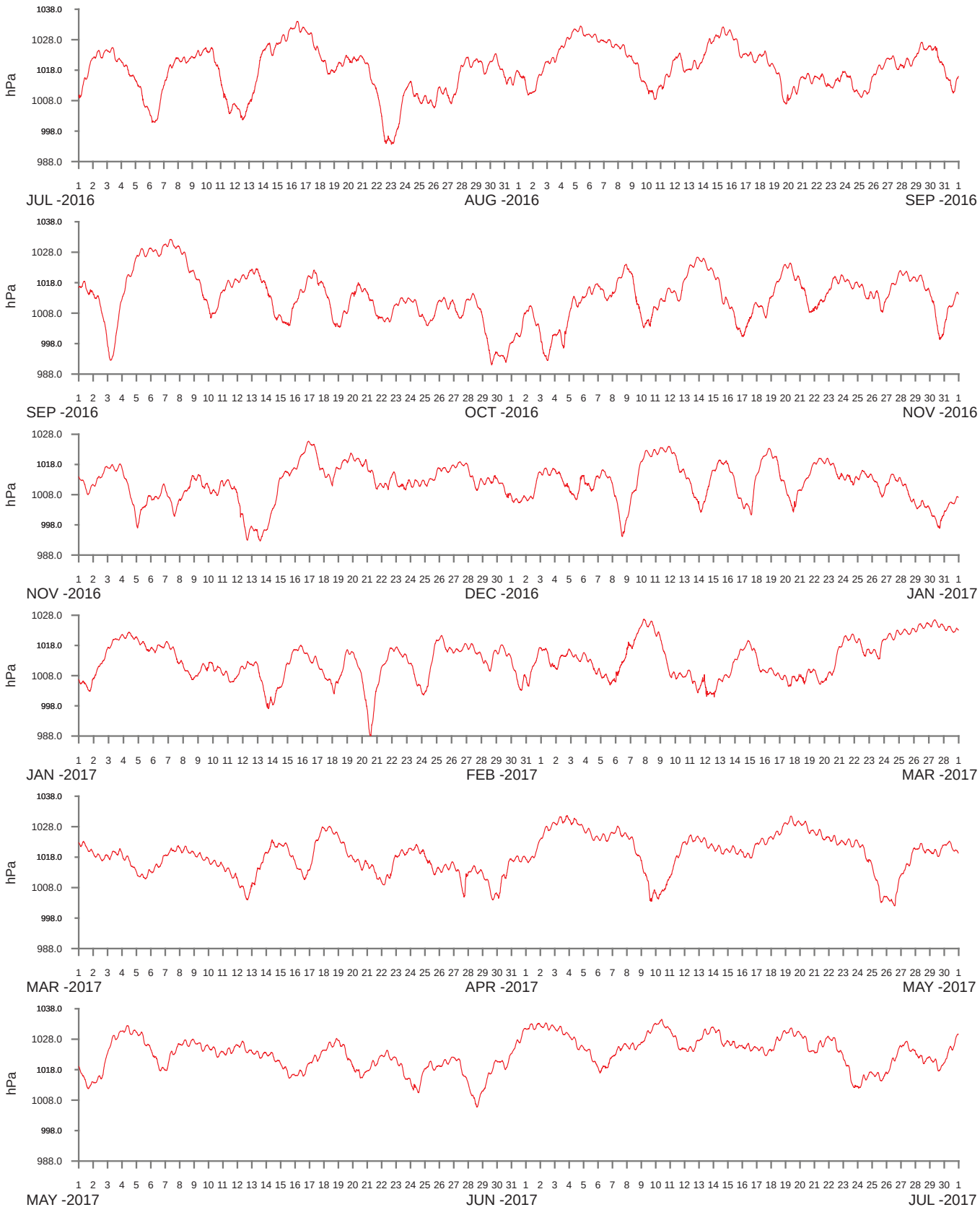
NSW GOVERNMENT Manly Hydraulics Laboratory

JERVIS BAY BAROMETER
2016–2017 AIR PRESSURE

MHL Report 2576

Figure 8.6

DRAWING 2576-08-06.cdr



BAROMETRIC PRESSURE REFERENCED TO MEAN SEA LEVEL

DATA LOSS

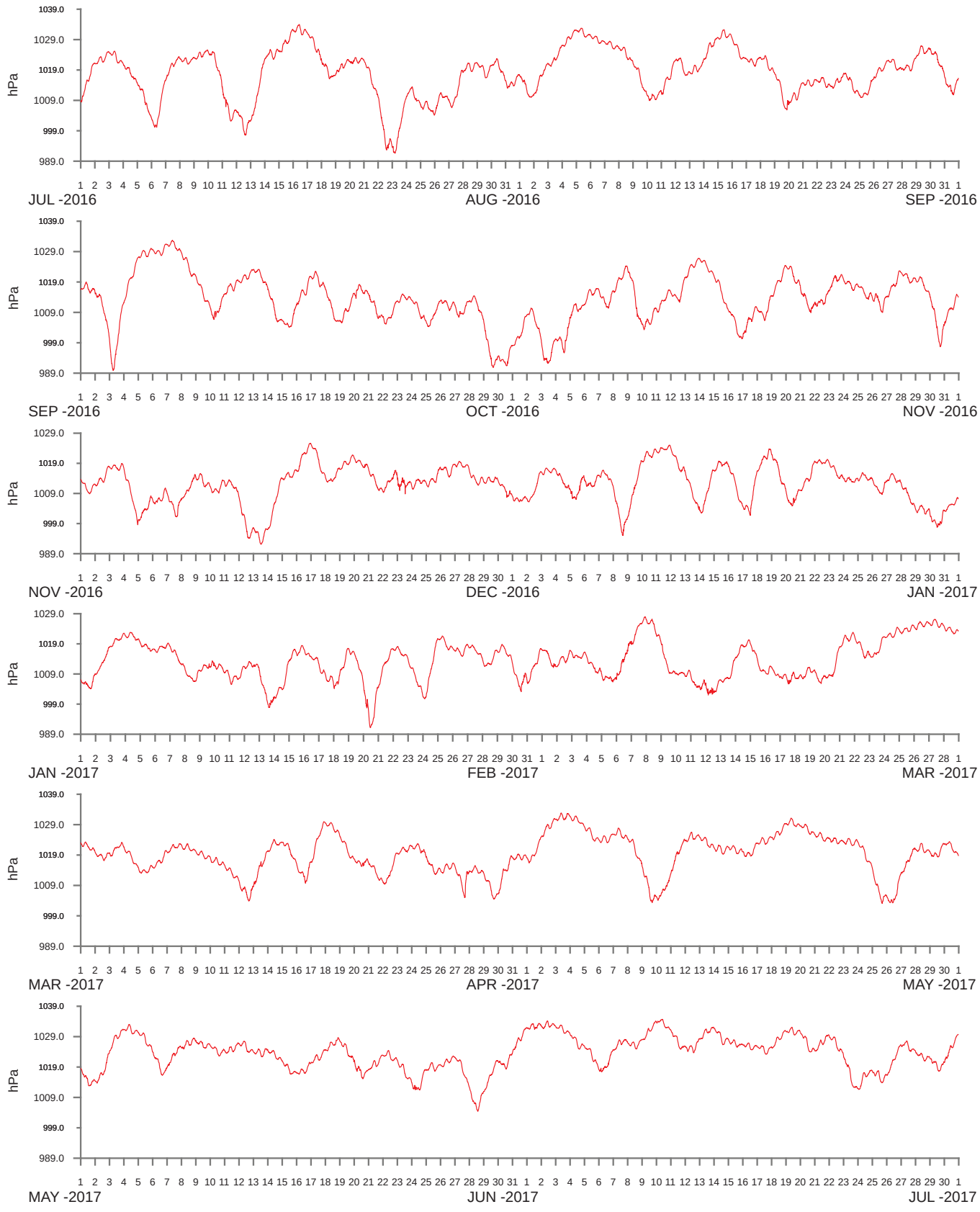
NSW GOVERNMENT Manly Hydraulics Laboratory

TUROSS HEAD BAROMETER
2016–2017 AIR PRESSURE

MHL Report 2576

Figure 8.7

DRAWING 2576-08-07.cdr



BAROMETRIC PRESSURE REFERENCED TO MEAN SEA LEVEL

DATA LOSS

NSW GOVERNMENT Manly Hydraulics Laboratory

EDEN BAROMETER
2016–2017 AIR PRESSURE

MHL Report 2576

Figure 8.8

DRAWING 2576-08-08.cdr

9. Air pressure data index

Since 1987 air pressure data has been collected at 15 locations along the New South Wales coast. Table 9.1 presents a summary of the barometer stations for which data has been quality controlled and referenced to mean sea level. Where possible, gaps in the barometer datasets have been patched using information recorded by nearby barometers operated by the Bureau of Meteorology.

Table 9.1 Air pressure data at Manly Hydraulics Laboratory – June 2017

Barometer site	Instrument	MGA location (Zone 56)		Barometer height	Data available		Record length	Data capture
		Easting	Northing	(m, MSL)	First date	Last date	(years)	(%)
Tweed Heads	MHL SPX100	554 010	6 884 210	20.0	06-Jun-1990	16-Dec-1994	4.53	100.0
Tweed Heads	Vaisala PTB 200	556 889	6 873 602	3.5	14-Oct-1999	Present	15.71	100.0
Byron Bay	MHL SPX100	562 040	6 831 590	100.0	22-Jul-1987	30-Sep-1999	12.19	100.0
Yamba (Palmers Is)	Vaisala PTB 200	529 490	6 739 613	3.7	24-Oct-1999	27-Sep-2009	9.93	100.0
Yamba	Vaisala PTB 200	530 459	6 739 060	3.2	27-Sep-2009	Present	5.76	100.0
Coffs Harbour	MHL SPX100	513 080	6 647 390	8.0	13-Jul-1987	30-Jun-1999	11.96	100.0
Port Macquarie	Vaisala PTB 200	490 494	6 525 126	3.0	15-Sep-1999	Present	15.79	100.0
Crowdy Head	MHL SPX100	476 344	6 477 095	4.0	24-Jul-1987	17-Jan-2000	12.49	100.0
Newcastle	Vaisala PTB 200	386 190	6 360 977	4.5	24-Feb-2000	Present	15.35	100.0
Sydney	Vaisala PTB 200	343 060	6 268 300	3.0	05-Aug-1999	Present	15.90	100.0
Sydney	MHL SPX100	338 590	6 260 600	25.0	08-May-1992	18-Oct-2000	8.45	100.0
Jervis Bay	Vaisala PTB 200	300 969	6 122 843	2.0	08-Feb-2000	Present	15.39	100.0
Tuross Heads	Vaisala PTB 200	240 879	6 005 121	3.5	22-Aug-2008	Present	5.86	100.0
Narooma	Vaisala PTB 200	242 095	5 988 377	2.3	09-Feb-2000	22-Aug-2008	8.53	99.9
Eden *	Vaisala PTB 200	759 050	5 873 050	2.6	10-Feb-2000	Present	15.38	99.6

* Location is relative to origin of Zone 55

Appendix A Sample data presentation formats

TIME SERIES WAVE STATISTICS

- table available as a Microsoft Excel or text file
- all analysed data between nominated dates / times
- any wave data parameter can be selected
- for explanation of statistics see Glossary

© NSW PUBLIC WORKS
MANLY HYDRAULICS LABORATORY

© OFFICE OF ENVIRONMENT AND HERITAGE

Date Generated: 25-Nov-15

COFFS HARBOUR WAVE DATA

Selection Restrictions : DATA_STATUS <= 6.0000

Date/Time	Hmean (m)	Hsig (m)	Hmax (m)	Tz (s)	T P1 (s)	TP2 (s)	Wave Power (watts/m)	WDIR (deg TN)	Sea Temp (C)
21/02/2014 0:00	0.634	0.991	1.6	5.4	9.77	8.52	3886.9	94	25.1
21/02/2014 1:00	0.665	1.05	1.87	5.5	9.77	5.34	4318.6	103	25.05
21/02/2014 2:00	0.627	0.99	1.63	5.36	9.77	8.9	3842.5	106	25.05
21/02/2014 3:00	0.607	0.966	1.55	5.28	9.77	5.8	3521	103	25.05
21/02/2014 4:00	0.606	0.978	2.04	5.27	9.32	5.98	3602.4	117	25.05
21/02/2014 5:00	0.573	0.916	1.65	5.15	9.32	8.52	3221.3	153	25
21/02/2014 6:00	0.581	0.923	1.54	5.19	9.32	6.56	3348.3	129	24.95
21/02/2014 7:00	0.579	0.907	1.53	4.99	8.9	5.34	3162.2	132	24.8
21/02/2014 8:00	0.616	0.978	2.21	4.78	9.77	8.52	3311.8	99	24.7
21/02/2014 9:00	0.645	1.017	1.75	4.99	9.32	7.85	3991.3	119	24.6
21/02/2014 10:00	0.685	1.069	1.75	5.04	9.32	5.2	4094.4	151	24.55
21/02/2014 11:00	0.735	1.155	2.35	5.15	8.9	6.16	5069.8	154	24.6
21/02/2014 12:00	0.767	1.211	2.57	5.06	9.77	8.9	5460.6	167	24.8
21/02/2014 13:00	0.853	1.341	2.92	5.41	9.32	6.36	6627.7	162	24.95
21/02/2014 14:00	0.939	1.456	2.52	5.31	6.79	5.98	7897.4	157	24.9
21/02/2014 15:00	0.988	1.543	2.83	5.29	6.56	5.8	8522.5	174	25.1
21/02/2014 16:00	1.01	1.612	2.69	5.41	8.9	6.36	8852	147	25.1
21/02/2014 17:00	1.015	1.605	2.59	5.25	6.36	5.48	9400.8	175	24.95
21/02/2014 18:00	1.02	1.61	2.93	5.31	9.32	6.36	9912.2	148	24.75
21/02/2014 19:00	0.906	1.445	3.13	5.12	9.32	6.16	7790	153	24.5
21/02/2014 20:00	0.914	1.42	2.56	5.26	9.77	5.98	7917.2	164	24.15
21/02/2014 21:00	0.867	1.352	2.3	5.27	8.9	7.03	7136.6	139	24.4
21/02/2014 22:00	0.867	1.368	2.37	5.47	8.17	7.28	7317.5	133	24.95

STORM HISTORY TABLES

- table available as a Microsoft Excel file
- table provides storm start and finish dates
- lists duration in hours of H_{sig} exceedance for 3 metre to 8 metre thresholds in 0.5 metre increments for every recorded storm
- includes peak H_{sig}, H_{max} and wave power, mean H_{sig}, T_{sig}, T_{P1} and wave power recorded during storm
- deepwater wave direction (measured or hindcast) at storm peak (maximum recorded H_{sig}) is included
- blue text indicates full duration of storm not recorded
- for explanation of statistics see Glossary

NSW Wave Climate

Crowdy Head Waverider Buoy Storm History

Site Commissioned: 10-Oct-85

Date Capture: 85.2%

Storm Date		Storm Duration (Hours) of Hsig (m) greater than:											Peak Hsig	Mean Hsig	Peak Hmax	Mean Tsig	Mean TP1	Peak Power	Mean Power	Deepwater Wave Direction	
Start	Finish	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	(m)	(m)	(m)	(s)	(s)	(kW/m)	(kW/m)	(° TN)	(Compass)
20-Oct-85	20-Oct-85	4	0	0	0	0	0	0	0	0	0	0	3.1	3.1	5.7	8.8	10.0	43.9	42.4	180	S
25-Oct-85	28-Oct-85	58	32	14	1	0	0	0	0	0	0	0	4.5	3.6	8.4	9.6	11.6	124.3	72.5	135	SE
18-Nov-85	19-Nov-85	3	0	0	0	0	0	0	0	0	0	0	3.2	3.2	6.5	9.8	11.2	56.6	54.7	180	S
22-Nov-85	22-Nov-85	1	0	0	0	0	0	0	0	0	0	0	3.0	3.0	4.6	7.9	10.2	41.5	41.5	180	S
23-Jan-86	25-Jan-86	27	10	2	0	0	0	0	0	0	0	0	4.1	3.4	7.3	8.5	9.9	79.7	54.5	90	E
12-May-86	15-May-86	28	21	13	6	3	0	0	0	0	0	0	5.1	4.0	8.7	8.1	8.8	114.8	71.0	90	E
15-Jun-86	18-Jun-86	48	29	8	1	0	0	0	0	0	0	0	4.5	3.6	8.3	9.7	10.6	100.1	67.7	90	E
30-Jun-86	1-Jul-86	15	5	0	0	0	0	0	0	0	0	0	3.7	3.3	6.4	11.8	13.3	93.6	74.5	135	SE
11-Jul-86	12-Jul-86	11	4	0	0	0	0	0	0	0	0	0	3.8	3.4	7.8	11.2	12.5	91.1	70.4	157	SSE
26-Jul-86	26-Jul-86	17	1	0	0	0	0	0	0	0	0	0	3.7	3.2	5.5	11.0	13.1	96.3	63.8	180	S
4-Aug-86	12-Aug-86	128	85	50	37	20	6	0	0	0	0	0	5.9	4.0	12.6	10.1	11.8	216.6	95.4	135	SE
22-Oct-86	22-Oct-86	1	0	0	0	0	0	0	0	0	0	0	3.0	3.0	4.3	7.6	7.7	35.0	35.0	135	SE
21-Nov-86	22-Nov-86	28	16	3	0	0	0	0	0	0	0	0	4.2	3.6	7.8	11.3	13.2	126.6	85.7	157	SSE
30-Nov-86	30-Nov-86	13	0	0	0	0	0	0	0	0	0	0	3.4	3.2	6.2	9.9	10.8	67.5	54.3	135	SE
9-Dec-86	9-Dec-86	5	3	0	0	0	0	0	0	0	0	0	3.8	3.4	6.9	8.2	10.2	68.3	53.0	180	S
17-Mar-87	17-Mar-87	1	0	0	0	0	0	0	0	0	0	0	3.3	3.3	5.5	9.2	11.1	53.4	53.4	112	ESE
31-Mar-87	1-Apr-87	16	6	1	0	0	0	0	0	0	0	0	4.0	3.4	7.7	10.9	12.9	111.2	78.3	180	S
9-Apr-87	10-Apr-87	31	19	9	1	0	0	0	0	0	0	0	4.5	3.7	8.0	9.1	11.2	102.2	73.8	180	S
18-May-87	19-May-87	31	9	0	0	0	0	0	0	0	0	0	3.8	3.4	7.3	10.6	12.0	88.1	69.0	180	S
28-May-87	28-May-87	5	1	0	0	0	0	0	0	0	0	0	3.5	3.2	6.5	10.1	12.2	69.5	58.7	180	S
12-Jul-87	13-Jul-87	14	0	0	0	0	0	0	0	0	0	0	3.3	3.1	5.9	9.3	11.1	55.2	49.8	180	S
4-Aug-87	4-Aug-87	9	1	0	0	0	0	0	0	0	0	0	3.5	3.3	5.9	11.1	12.9	82.4	68.8	180	S
18-Aug-87	18-Aug-87	3	0	0	0	0	0	0	0	0	0	0	3.3	3.2	5.6	9.1	9.5	50.9	48.3	112	ESE
1-Sep-87	2-Sep-87	33	16	9	2	0	0	0	0	0	0	0	4.8	3.6	8.1	11.8	13.5	173.4	93.9	180	S
1-Oct-87	1-Oct-87	6	4	0	0	0	0	0	0	0	0	0	3.8	3.4	6.1	9.6	10.7	77.5	62.0	180	S
5-Oct-87	6-Oct-87	16	7	2	0	0	0	0	0	0	0	0	4.3	3.5	7.1	10.5	11.9	115.2	72.8	135	SE

Appendix B Glossary of terms

Air / Barometric Pressure	:	the pressure of the atmosphere at a location due to the weight of a column of air above it. Air pressure is measured in hectopascals (hPa).
Average H_{sig}	:	average significant wave height recorded during a storm event.
Average T_{P1}	:	average spectral peak period recorded during a storm event.
Average T_{sig}	:	average significant wave period recorded during a storm event.
Average Wave Power	:	average wave power level recorded during a storm event.
Barometer	:	a device used to measure variations in atmospheric pressure.
Correlation Coefficient	:	measurement (between -1 and 1) of the quality of fit of a line through a set of data points. The closer the number to ± 1 the better the fit.
Data Capture / Data Recovery	:	number of records collected divided by total number of possible records. Normally expressed as a percentage.
Date / Time	:	for start of record.
Deep Water	:	water sufficiently deep that surface waves are little affected by the ocean bottom. Generally, water deeper than one-half the surface wave length is considered deep water.
Diffraction	:	the 'spreading' of waves into the lee of obstacles such as breakwaters by the transfer of wave energy along wave crests. Diffracted waves are lower in height than the incident waves.
Directional Waverider Buoy	:	a floating device used to measure ocean wave height, period and direction. It is a registered trademark of the Dutch company Datawell.
E	:	Normalised Spectral Estimate.
Effective Record Length	:	total record length multiplied by the data capture rate.
Electromagnetic Current Meter	:	a device that measures current and water pressure variations. If deployed in shallow water current and pressure data can be converted to wave height, period and direction. Current meters manufactured by the American companies Marsh McBirney and InterOcean are used by Manly Hydraulics Laboratory to collect wave data.
Electromagnetic Wave and Tide Monitoring System (EWS)	:	linear electromagnetic gauge fixed to a structure used to measure water level variations caused by waves and tides.
ERR	:	number of corrections or 'patches' in a record.
Fetch	:	the horizontal distance over which a wind blows in generating waves.
Filtered Data	:	raw data modified to remove wind waves, tide or some other frequency components.
Hindcast	:	the prediction of wave characteristics using meteorological information as opposed to the measurements of these features.
H_1	:	average height of the waves which comprise the top 1%.
H_{10}	:	average height of the waves which comprise the top 10%.
H_{max}	:	maximum wave height.
H_{mean}	:	mean wave height.
H_{rms}	:	root mean square wave height.

H_{sig}	:	significant wave height = average height of the waves which comprise the top 33%.
LEN	:	accepted record duration (normally in seconds).
Logger	:	device for recording digitised data.
Long Wave	:	waves with periods greater than 30 seconds. Often associated with storm wave activity along the NSW coast.
M_0, M_1, M_2, M_3	:	Spectral Moments - $M_n = \Sigma\ E\ f^n\ \Delta f$. These provide parameters describing the shape of the spectrum.
MS	:	Mean Square displacement (= Y_{rms}^2 = M_0).
NPTS	:	number of sample points in a record.
$\frac{P2}{P1}$ or $\frac{SP2}{SP1}$	:	ratio of second highest spectral peak to the highest.
Peak H_{max}	:	highest maximum wave height recorded during a storm event.
Peak H_{sig}	:	highest significant wave height recorded during a storm event.
Peak Wave Power	:	maximum wave power level recorded during a storm event.
Percentage Exceedance	:	percentage of time that a given value is exceeded.
Percentage Occurrence	:	percentage of time that given value (or range of values) occurs.
Receiver	:	shore-based device for receiving incoming wave signals.
Record	:	burst of data from the wave measuring device (usually 2048 seconds).
Record Interval	:	time between records (usually 1 hour). Prior to June 1984 the standard for wave data collection by Manly Hydraulics Laboratory was 6 hours.
Refraction	:	the tendency of wave crests to become parallel to bottom contours as waves move into shallower waters. This effect is caused by the shoaling process which slows down waves in shallower waters.
Return Period	:	expected average interval between the occurrences of events at a particular threshold.
S	:	Spectral Estimate = E x M_0.
S.E.	:	Standard Error = rms y-deviation of data points from a fitted line.
Sample Increment	:	time between sample points measured by the transducer. Sample points are normally spaced at 0.5 second intervals for ocean wave measurement.
Sea Waves	:	waves in coastal waters resulting from the interaction of different wave trains and locally generated waves. Typically, sea waves are of short wave length and of disordered appearance.
Shallow Water	:	water of such a depth that surface waves are noticeably affected by bottom topography. Generally, water depth less than one-half the surface wave length is considered shallow water.
Shoaling	:	the influence of the seabed on wave behaviour. Such effects only become significant in water depths of 60 m or less. Manifested as a reduction in wave speed, a shortening in wave length and an increase in wave height.
Storm Event	:	period of high wave activity. For the NSW coastline is normally defined as the time when a H_{sig} greater than 3 metres is recorded at an offshore wave recording station.

Swell Waves	:	wind waves remote from the area of generation (fetch) having a uniform and orderly appearance characterised by regularly spaced wave crests.
Total Record Length	:	elapsed period from the date of commission to the end of data collection at a recording site.
T_c	:	crest period = average time between successive crests.
T_{P1}	:	peak period of the energy spectrum.
T_{P2}	:	period corresponding to the second biggest peak of the energy spectrum.
T_{sig}	:	significant period = average period of the waves used to define H_{sig}.
T_z	:	zero crossing period = mean period.
Wave Direction	:	the direction from which ocean waves approach a location. Generally, the principal wave direction is represented by the direction that corresponds to the peak period of the energy spectrum (T_{P1}).
Wave Height	:	the vertical distance between a wave trough and wave crest.
Wave Length	:	the distance between consecutive wave crest or wave troughs.
Wave Period	:	the time taken for consecutive wave crests or wave troughs to pass a given point.
Wave Power	:	the rate at which wave energy is transmitted in the direction of wave propagation. Normally expressed in kilowatts per metre of wave crest length.
Waverider Buoy	:	a floating device used to measure water level variations caused by ocean waves. It is a registered trademark of the Dutch company Datawell.
Wind Waves	:	the waves initially formed by the action of wind blowing over the sea surface. Wind waves are characterised by a range of heights, periods and wave lengths. As they leave the area of generation (fetch), wind waves develop a more ordered and uniform appearance and are referred to as swell or swell waves.
Y_{rms}	:	root mean square amplitude (not to be confused with H_{rms}).

Appendix C Bibliography

1. Wave data collection and analysis – general

Barstow, S.F. and Kollstad, T., Field trials of the Directional Waverider, *First International Offshore and Polar Engineering Conference,* Edinburgh, United Kingdom, August 1991.

Borgman, L.E., Confidence Intervals for Ocean Wave Spectra, *13th International Coastal Engineering Conference,* Vancouver, 1972.

CSIR, *Comparative field tests of a Datawell Directional Waverider and an Electromagnetic Current Meter Pressure Sensor Instrument*, CSIR Report EMAS-T93003, Stellenbosch, February 1993.

Datawell b.v., *Warec - PC Software*, Datawell b.v. - Laboratory for Instrumentation, October 1992.

Datawell b.v., *Manual of the Digital Waverider Receiver type DIWAR,* Datawell b.v. - Laboratory for Instrumentation, February 1998.

Datawell b.v., *Manual for the Wave Direction Receiver 'WAREC'*, Datawell b.v. - Laboratory for Instrumentation, April 1998.

Datawell b.v., *Datawell Directional Waverider Manual Mark II*, Datawell b.v. – Laboratory for Instrumentation, June 2004.

Datawell b.v., *Datawell Waverider Installation Guide,* Datawell b.v. - Laboratory for Instrumentation, June 2005.

Datawell b.v., *Datawell Waverider Receiver Manual RX-D type 2,* Datawell b.v. - Laboratory for Instrumentation, November 2005.

Datawell b.v., *Datawell Waverider Reference Manual, WR-SG, DWR-MkIII, DWR-G*, Datawell b.v. – Laboratory for Instrumentation, March 2007.

Datawell b.v., *Datawell Waverider Reference Manual (including FB2 electronics unit) WR-SG, DWR-MkIII*, Datawell b.v. – Laboratory for Instrumentation, June 2011.

Draper L., The Analysis and Presentation of Wave Data - A Plea for Uniformity, *10th International Coastal Engineering Conference,* Japan, September 1966.

Goda, Y., Wave Measurements and Utilisation of Wave Data, *6th Australian Conference on Coastal and Ocean Engineering,* Brisbane, Institution of Engineers, Australia, July 1983.

Hamilton, L.J*., Bibliography of Wind-Wave Data and Publications for the Coastal Regions of Australia*, Department of Defence, Defence Science and Technology Organisation, Report DSTO-GD-0116, February 1997.

Harris, D.L., Analysis of Wave Records, *12th International Coastal Engineering Conference,* Washington, September 1970.

Harris, D.L., Finite Spectrum Analysis of Wave Records, *International Symposium on Ocean Wave Measurement and Analysis*, New Orleans, September 1974.

Kuik, A.J. and Holthuijsen, L.H., Buoy Observation of Directional Wave Parameters, *Conference on Directional Wave Spectra Applications,* Berkeley, California, American Society of Civil Engineers, September 1981.

Kuik, A.J. and van Vledder, G., Proposed Method for the Routine Analysis of Pitch-Roll Buoy Data, *Symposium on Description and Modelling of Directional Seas*, Denmark, Danish Hydraulic Institute and Danish Maritime Institute, June 1984.

Lawson, N.V., Rice, R.A. and Szylkarski, S.P., World Satellite Altimeter Wave Data Base, *11th Australasian Conference on Coastal and Ocean Engineering*, Townsville, Institution of Engineers, Australia, August 1993.

MacLaren Plansearch Limited, *Evaluation/Validation of the new Datawell Directional Waverider Buoy*, Report 05889SRE.001, Nova Scotia, Canada, 1991.

Mansard, E.P.D. and Funke, E.R., A Comprehensive Wave Data Analysis Package, *International Conference on Measuring Techniques of Hydraulic Phenomena in Offshore, Coastal and Inland Waters,* London, BHRA, The Fluid Engineering Centre, April 1986.

Oceanographic Company of Norway A/S., *Field Trials of the Directional Waverider*, Trondheim, Norway.

Pitt, E.C. Pascall, R.W. and van Heteren, J., A Comparison of the Measurements made by two Pitch-Roll Buoys during the NURWEC Project*, Ocean-Data Conference - Evaluation, Comparison and Calibration of Ocean Instruments*, London, 1985.

Reid, J.S., Some Comments on Ocean Wave Statistics, *9th Australasian Conference on Coastal and Ocean Engineering,* Adelaide, Institution of Engineers, Australia, December 1989.

Siefert, W., Shallow Water Wave Characteristics, *13th International Coastal Engineering Conference,* Vancouver, 1972.

Tremarfon Pty Ltd, *Ocean Wave Data Collection System Software Guide*, Tremarfon Pty Ltd for Manly Hydraulics Laboratory, September 2006.

Thompson, W.G., Swell and Storm Characteristics from Coastal Wave Records, *12th International Coastal Engineering Conference,* Washington, September 1970.

Tucker, M.J., *Waves in Ocean Engineering, measurement, analysis and interpretation*, Ellis Horwood Limited, 1991.

Tucker, M.J., *Recommended Standard for Wave Data Sampling and Near Real-time Processing*, Oil Industry International Exploration and Production Forum, London, Report No. 3.14/186, June 1992.

van der Vlugt, A.J.M., Kuik, A.J. and Holthuijsen, The Wavec Directional Buoy under Development, *Conference on Directional Wave Spectra Applications*, Berkeley, California, American Society of Civil Engineers, September 1981.

van der Vlugt, A.J.M., The Wavec Buoy for Routinely Measuring the Direction of Sea Waves, *International Conference on Wave and Wind Directionality Applications to the Design of Structures,* Paris, September 1981.

van der Vlugt, A.J.M., Experience with the Wavec Buoy, *Symposium on Description and Modelling of Directional Seas*, Denmark, Danish Hydraulic Institute and Danish Maritime Institute, June 1984.

Wang, S. and Le Mehaute, B., Duration of Measurements and Long-Term Wave Statistics, *Journal of Waterway Port Coastal and Ocean Engineering,* Vol. 109 No. 2, American Society of Civil Engineers, May 1983.

Waters, C.B., Experiences in the Operation of Waverider Buoys, *16th Congress International Association for Hydraulic Research,* Brazil, 1975.

Wilson, J.R. and Baird, W.F., A Discussion of Some Measured Wave Data, *13th International Coastal Engineering Conference,* Vancouver, 1972.

2. Wave data collection and analysis – New South Wales

Abernethy, C.L. and Lawson, N.V., Statistical Distributions of Wave Parameters off Botany Bay, *1st Australian Conference on Coastal Engineering*, Sydney, Institution of Engineers, Australia, May 1973.

Allan, A.J., Bolton, A.W. and Webb, A.T., A Second Generation Wave Recording Network, *International Conference on Measuring Techniques of Hydraulic Phenomena in Offshore, Coastal and Inland Waters,* London. BHRA, The Fluid Engineering Centre, April 1986.

Australian Water and Coastal Studies Pty Ltd, *DWAVE - Wave Data Software Wave Power Statistics User's Guide,* Report No. 90/07, July 1990.

Australian Water and Coastal Studies Pty Ltd, *Wave Power Study for Selected Sites along the New South Wales Coastline,* Report No. 91/08, May 1991.

Australian Water and Coastal Studies Pty Ltd, *Sydney Deepwater Outfalls Environmental Monitoring Program, Post Commissioning Phase, An Examination of Ocean Reference Station Wind and Wave Data*, Interim Report 93/01/14, December 1995.

Coghlan, I., Mole, M., Shand, T., Carley, J., Peirson, W., Miller, B., Kulmar, M., Couriel, E., Modra, B. and You, Z.J., *High Resolution Wave Modelling (HI-WAM) for Batemans Bay Detailed Wave Study*, Coasts and Ports 2011 Conference, Perth, Australia, September 2011.

Department of Finance and Services, *Batemans Bay Wave Climate Study*, Manly Hydraulics Laboratory, Report MHL2003, December 2010.

Department of Public Works and Services, *New South Wales Central Coast 1995 Wave Data Analysis*, Manly Hydraulics Laboratory, Report MHL754, June 1997.

Department of Public Works and Services, *New South Wales Coast May 1997 Storm Analysis*, Manly Hydraulics Laboratory, Report MHL886, December 1997.

Foster, D., Gordon, A.D. and Lawson, N.V., The Storms of May-June 1974, Sydney, NSW, *2nd Australian Conference on Coastal and Ocean Engineering,* Gold Coast, Institution of Engineers, Australia, April 1975.

Gordon, A.D., Beach Fluctuations and Shoreline Change, *8th Australasian Conference on Coastal and Ocean Engineering,* Launceston, Institution of Engineers, Australia, December 1987.

Jayewardene, I.F.W., Haradasa, D.K.C. and Tainsh, J., Analysis of Wave Groupiness, *11th Australasian Conference on Coastal and Ocean Engineering,* Townsville, Institution of Engineers, Australia, August 1993.

Kemp, R., Gage, B., Moodie, N. and Kulmar, M., Climatology of Large Wave Events and Associated Weather Systems Along the NSW Coast, *16th Australasian Coastal and Ocean Engineering Conference*, Institution of Engineers, Australia, Auckland, NZ, September 2003.

Kulmar, M.A., Wave Direction Distributions off Sydney, New South Wales, *12th Australasian Coastal and Ocean Engineering Conference*, Melbourne, Institution of Engineers, Australia, May 1995.

Kulmar, M., Lord, D. and Sanderson, B., Future Directions for Wave Data Collection in New South Wales, *17th Australasian Conference on Coastal and Ocean Engineering*, Adelaide, Engineers Australia, September 2005.

Kulmar, M., Modra, B. and Fitzhenry, M., The New South Wales Wave Climate – Improved Understanding through the Introduction of Directional Wave Monitoring Buoys, *2013 Australasian Coasts and Ports Conference*, Sydney, Engineers Australia, September 2013.

Lawson, N.V. and Abernethy, C.L., Long Term Wave Statistics off Botany Bay, *2nd Australian Conference on Coastal and Ocean Engineering,* Gold Coast, Institution of Engineers, Australia, April 1975.

Lawson, N.V., McCowan, A.D. and Treloar, P.D., Inter-Relationships between Wave Periods for the NSW, Australia Coast, *8th Australasian Conference on Coastal and Ocean Engineering,* Launceston, Institution of Engineers, Australia, December 1987.

Lawson, N.V. and Youll, P.H., Storm Duration and Return Interval for Waves off the Central NSW Coast, *3rd Australian Conference on Coastal and Ocean Engineering,* Melbourne, Institution of Engineers, Australia, April 1977.

Lawson, N.V. and Youll, P.H., Realtime Wave Analysis, Newcastle, Australia, *17th International Conference on Coastal Engineering,* Sydney, Institution of Engineers, Australia, March 1980.

Lord, D. and Kulmar, M.A., The 1974 Storms Revisited: 25 years Experience in Ocean Wave Measurement along the South-East Australian Coast, *27th International Conference on Coastal Engineering*, Sydney, Institution of Engineers, Australia, July 2000.

McMonagle, C.J. and Fidge, B.L., A Study of Extreme Values of Water Level and Wave Height at Coffs Harbour, *5th Australian Conference on Coastal and Ocean Engineering,* Perth, Institution of Engineers, Australia, November 1981.

NSW Public Works, *Waverider User Manual*, Manly Hydraulics Laboratory, Version 3.4, June 1993.

NSW Public Works, *Wave Direction Study - Satellite Imagery Progress Report No.2*, Manly Hydraulics Laboratory, Report MHL641, March 1993.

NSW Public Works, *Sydney Directional Waverider Buoy*, Manly Hydraulics Laboratory, Interim Report MHL656, April 1995.

NSW Public Works, *Batemans Bay Wave Climate Study*, Manly Hydraulics Laboratory, Draft Report MHL2003, October 2010.

Public Works Department, NSW, *Wave Data Collection at Manly Laboratory,* Manly Hydraulics Laboratory, Report MHL311, April 1982.

Public Works Department, NSW, *Wave Statistics for Port Kembla,* Manly Hydraulics Laboratory, Report MHL416, August 1984.

Public Works Department, NSW, *Comparison of Wave Statistics between Byron Bay and Coffs Harbour,* Manly Hydraulics Laboratory, Report MHL422, November 1984.

Public Works Department, NSW, *DWAVE Data Presentation,* Manly Hydraulics Laboratory, Report MHL427, September 1985.

Public Works Department, NSW, *Wave Data Conditioning,* Manly Hydraulics Laboratory, Report MHL436, August 1985.

Public Works Department, NSW, *Hand Reduction of Wave Data for Port Kembla, 1974-1983,* Manly Hydraulics Laboratory, Report MHL442, November, 1985.

Public Works Department, NSW, *Elevated Ocean Levels - Storms Affecting the NSW Coast 1880-1980,* Coastal Branch, Report No. 85041, December 1985.

Public Works Department, NSW, *Development of a Radar Facility to Measure Wave Direction and Currents,* Manly Hydraulics Laboratory, Report MHL456, April 1986.

Public Works Department, NSW, *Elevated Ocean Levels - Storms Affecting the NSW Coast 1980-1985,* Coastal Branch, Report No. 86026, August 1986.

Public Works Department, NSW, *DWAVE - Wave Data Software*, Manly Hydraulics Laboratory, Report MHL399, July 1987.

Public Works Department, NSW, *Zwarts User's Manual*, Manly Hydraulics Laboratory, Report MHL406, Revised Edition, July 1987.

Public Works Department, NSW, *Jervis Bay Wave and Tide Data,* Manly Hydraulics Laboratory, Report MHL476, June 1988.

Public Works Department, NSW, *Nelson Bay Wave Data,* Manly Hydraulics Laboratory, Report MHL543, July 1988.

Public Works Department, NSW, *Eden Wave Data Collection Network,* Manly Hydraulics Laboratory, Report MHL542, November 1988.

Public Works Department, NSW, *Batemans Bay Oceanographic and Meteorological Data 1986-89*, Manly Hydraulics Laboratory, Report MHL556, August 1990.

Public Works Department, NSW, *Storm Surges Monitored along the NSW Coast March - April 1990,* Manly Hydraulics Laboratory, Report MHL591, November 1991.

Short, A.D., *Beaches of the New South Wales Coast - a Guide to their Nature, Characteristics, Surf and Safety*, Australian Beach Safety and Management Program, 1993.

Tremarfon Pty Ltd, *Ocean Wave Data Collection System Software Guide*, September 2010.

Trenaman, N.L. and Short, A.D., *Deepwater and Breaker Wave Climate of the Sydney Region New South Wales 1971-1985,* Coastal Studies Unit, The University of Sydney, Report No. 87/1, December 1987.

University of New South Wales, *NSW Coastal Inundation Hazard Study: Coastal Storms and Extreme Waves,* Water Research Laboratory and Macquarie University, WRL Technical Report 2010/16, January 2011.

Watson, P., Lord, D., Kulmar, M., McLuckie, D. and James, J., Analysis of a Storm – June 2007, *16th NSW Coastal Conference,* Yamba, Clarence Valley Council, November 2007.

Webb, A.T., Wave Climate of the New South Wales Coast, *6th Australian Conference on Coastal and Ocean Engineering,* Gold Coast, Institution of Engineers, Australia, July 1983.

Webb, A.T. and Bolton, A.W., Wave Data on Tap, *8th Australasian Conference on Coastal Engineering,* Launceston, Institution of Engineers, Australia, December 1987.

Webb, A.T. and Kulmar, M.A., Coastal Wave Climate of New South Wales - An Update, *9th Australasian Conference on Coastal and Ocean Engineering,* Adelaide, Institution of Engineers, Australia, December 1989.

Wyllie, S.J., Kulmar, M.A. and Davidson, P.J., Development of Design Offshore Wave and Ocean Level Conditions for the New South Wales Coastal Zone, *2nd Coastal Management Conference,* Kiama, Kiama Municipal Council, November 1992.

Wyllie, S.J. and Kulmar, M.A., Coastal Wave Monitoring, *Australian Marine Data Collection and Management Guidelines Workshop*, Hobart, Environmental Resources Information Network, December 1995.

Willoughby, M.A., NSW Central Coast Wave Climate - 1995 Update, *12th Australasian Coastal and Ocean Engineering Conference*, Melbourne, Institution of Engineers, Australia, May 1995.

You, Z.J. and Jayewardene, I., The Occurrence of Extreme Coastal Storms Along the NSW Coast, *National Environment Conference*, Brisbane, 2003.

You, Z.J. and Lord, D., Influence of the El Nino Southern Oscillation on the NSW Coastal Storm Severity, *Journal of Coastal Research*, 24: 203-207, 2008.

You, Z.J., Extrapolation of extreme wave height with a proper probability distribution function, *Australasian Coasts and Ports Conference*, 17-20 July, Melbourne, 2008.

Youll, P.H., Botany Bay Waverider System - Ten Years of Records, *5th Australian Conference on Coastal and Ocean Engineering,* Perth, Institution of Engineers, Australia, November 1981.

3. New South Wales wave climate annual summaries

Public Works Department, NSW, *New South Wales Wave Climate Annual Summary 1985/86*, Manly Hydraulics Laboratory, Report MHL465, September 1986.

Public Works Department, NSW, *New South Wales Wave Climate Annual Summary 1986/87*, Manly Hydraulics Laboratory, Report MHL520, October 1987.

Public Works Department, NSW, *New South Wales Wave Climate Annual Summary 1987/88*, Manly Hydraulics Laboratory, Report MHL547, October 1988.

Public Works Department, NSW, *New South Wales Wave Climate Annual Summary 1988/89*, Manly Hydraulics Laboratory, Report MHL560, November 1989.

Public Works Department, NSW, *New South Wales Wave Climate Annual Summary 1989/90*, Manly Hydraulics Laboratory, Report MHL581, October 1990.

Public Works Department, NSW, *New South Wales Wave Climate Annual Summary 1990/91*, Manly Hydraulics Laboratory, Report MHL600, September 1991.

Public Works Department, NSW, *New South Wales Wave Climate Annual Summary 1991/92*, Manly Hydraulics Laboratory, Report MHL627, October 1992.

NSW Public Works, *New South Wales Wave Climate Annual Summary 1992/93,* Manly Hydraulics Laboratory, Report MHL655, September 1993.

NSW Public Works, *New South Wales Wave Climate Annual Summary 1993/94,* Manly Hydraulics Laboratory, Report MHL695, October 1994.

Department of Public Works and Services, *New South Wales Wave Climate Annual Summary 1994/95,* Manly Hydraulics Laboratory, Report MHL733, November 1995.

Department of Public Works and Services, *New South Wales Wave Climate Annual Summary 1995/96,* Manly Hydraulics Laboratory, Report MHL779, August 1996.

Department of Public Works and Services, *New South Wales Wave Climate Annual Summary 1996-97,* Manly Hydraulics Laboratory, Report MHL877, September 1997.

Department of Public Works and Services, *New South Wales Wave Climate Annual Summary 1997-98*, Manly Hydraulics Laboratory, Report MHL948, October 1998.

Department of Public Works and Services, *New South Wales Wave Climate Annual Summary 1998-99*, Manly Hydraulics Laboratory, Report MHL1016, September 1999.

Department of Public Works and Services, *New South Wales Wave Climate and Coastal Air Pressure Annual Summary 1999-2000*, Manly Hydraulics Laboratory, Report MHL1072, October 2000.

Department of Public Works and Services, *New South Wales Wave Climate and Coastal Air Pressure Annual Summary 2000-2001*, Manly Hydraulics Laboratory, Report MHL1132, October 2001.

Department of Public Works and Services, *New South Wales Wave Climate and Coastal Air Pressure Annual Summary 2001-2002*, Manly Hydraulics Laboratory, Report MHL1208, March 2003.

Department of Commerce, *New South Wales Wave Climate and Coastal Air Pressure Annual Summary 2002-2003*, Manly Hydraulics Laboratory, Report MHL1279, October 2003.

Department of Commerce, *New South Wales Wave Climate and Coastal Air Pressure Annual Summary 2003-2004*, Manly Hydraulics Laboratory, Report MHL1349, October 2004.

Department of Commerce, *New South Wales Wave Climate and Coastal Air Pressure Annual Summary 2004-2005*, Manly Hydraulics Laboratory, Report MHL1425, November 2005.

Department of Commerce, *New South Wales Wave Climate and Coastal Air Pressure Annual Summary 2005-2006*, Manly Hydraulics Laboratory, Report MHL1514, March 2007.

Department of Commerce, *New South Wales Wave Climate and Coastal Air Pressure Annual Summary 2006-2007*, Manly Hydraulics Laboratory, Report MHL1766, March 2008.

Department of Commerce, *New South Wales Wave Climate and Coastal Air Pressure Annual Summary 2007-2008*, Manly Hydraulics Laboratory, Report MHL1850, September 2008.

Department of Commerce, *New South Wales Wave Climate and Coastal Air Pressure Annual Summary 2008-2009*, Manly Hydraulics Laboratory, Report MHL1935, November 2009.

Department of Services, Technology and Administration, *New South Wales Wave Climate and Coastal Air Pressure Annual Summary 2009-2010*, Manly Hydraulics Laboratory, Report MHL2012, November 2010.

Department of Finance and Services, *New South Wales Wave Climate and Coastal Air Pressure Annual Summary 2010-2011*, Manly Hydraulics Laboratory, Report MHL2091, December 2011.

Department of Finance and Services, *New South Wales Wave Climate and Coastal Air Pressure Annual Summary 2011-2012*, Manly Hydraulics Laboratory, Report MHL2160, November 2012.

Department of Finance and Services, *New South Wales Wave Climate and Coastal Air Pressure Annual Summary 2012-2013*, Manly Hydraulics Laboratory, Report MHL2221, November 2013.

Office of Finance and Services, *New South Wales Wave Climate and Coastal Air Pressure Annual Summary 2013-2014*, Manly Hydraulics Laboratory, Report MHL2294, March 2015.

Department of Finance, Services and Innovation, *New South Wales Wave Climate and Coastal Air Pressure Annual Summary 2014-2015*, Manly Hydraulics Laboratory, Report MHL2386, March 2016.

Department of Finance, Services and Innovation, *New South Wales Wave Climate and Coastal Air Pressure Annual Summary 2015-2016*, Manly Hydraulics Laboratory, Report MHL2477, November 2016.

4. Air pressure

Vaisala, *Operating Manual PTB 200 Digital Barometers*, Vaisala Oyj, February 1993.

110B King Street
Manly Vale NSW 2093

www.mhl.nsw.gov.au