NSW OCEAN AND RIVER ENTRANCE TIDAL LEVELS ANNUAL SUMMARY
2019–2020

Report MHL2770
December 2020

Prepared for:

NSW Department of Planning, Industry and Environment
Climate Change and Sustainability Division

Cover photograph: Forster ocean tide gauge aerial photograph taken using a drone
Forster, NSW, 6 June 2020
Photo courtesy of Eduardo Pombo Lavin

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Foreword

Manly Hydraulics Laboratory (MHL) is a business unit within the Water Group of the NSW Department of Planning, Industry and Environment. MHL operates and maintains ocean and river entrance tidal recording stations along the NSW coast under a service level agreement with the Climate Change and Sustainability Division of the NSW Department of Planning, Industry and Environment.

The NSW ocean tide database developed by MHL supports a number of Climate Change and Sustainability Division programs associated with coastal, floodplain and estuary management. These include the operations of ports and marine facilities, water level forecasts, fisheries management, determining property boundaries and developing a detailed understanding of oceanic processes. The monitoring service and outputs are available to local government and other organisations, both in Australia and overseas.

This summary provides information on how to access the ocean tide database and the data analysis capabilities of MHL.

The standards adopted for the program are those specified by the National Permanent Committee on Tides and Mean Sea Level hosted by the Australian Hydrographic Office.

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Summary

This annual summary presents ocean and river entrance tidal data captured by the automatic tide level recording stations along the coastline of NSW over the period 1 July 2019 to 30 June 2020. It provides a catalogue of all ocean and river entrance tidal data collected in NSW by MHL for the Climate Change and Sustainability Division.

The 2019–2020 data recovery rate for the 15-minute ocean tide data achieved 99.5%, which is higher than the service level target of 95%.

This report contains:

- a brief description of the ocean and river entrance tidal measurement program
- guidelines on how to use this report
- information on how to access the database
- a description of significant events which occurred in 2019–2020
- Appendix A, the annual data summaries for each site (see Figure 1.1 for site locations)
- Appendix B, detailing the tidal data available on line
- Appendix C, detailing the historical tidal data available
- Appendix D, which shows data output formats available from MHL
- Appendix E, a glossary of terms
- Appendix F, a list of other publications which may be of interest.

Contents

APPENDICES

TABLES

FIGURES

1. Tidal network measurement program

This report presents the thirty-fourth year of data collected by automatic ocean tide level recorders for the State of NSW. MHL provides tide data through a network of recorders and an efficient service of associated analysis routines.

The present program is based on a network of automatic ocean tide level recording stations installed at eighteen coastal and four offshore sites, and one open ocean site located on Lord Howe Island. Additional data for Norfolk Island is provided by the Bureau of Meteorology's National Tidal Unit (NTU) (Figure 1.1). The ocean tide monitoring network features three distinctive system types for data capture: radar, vented pressure sensor and submersed water level pressure recorder. Electromagnetic tide poles and solid state floatwells were also previously used to collect water level data in the ocean tide program.

The current ocean tide monitoring systems function as follows:

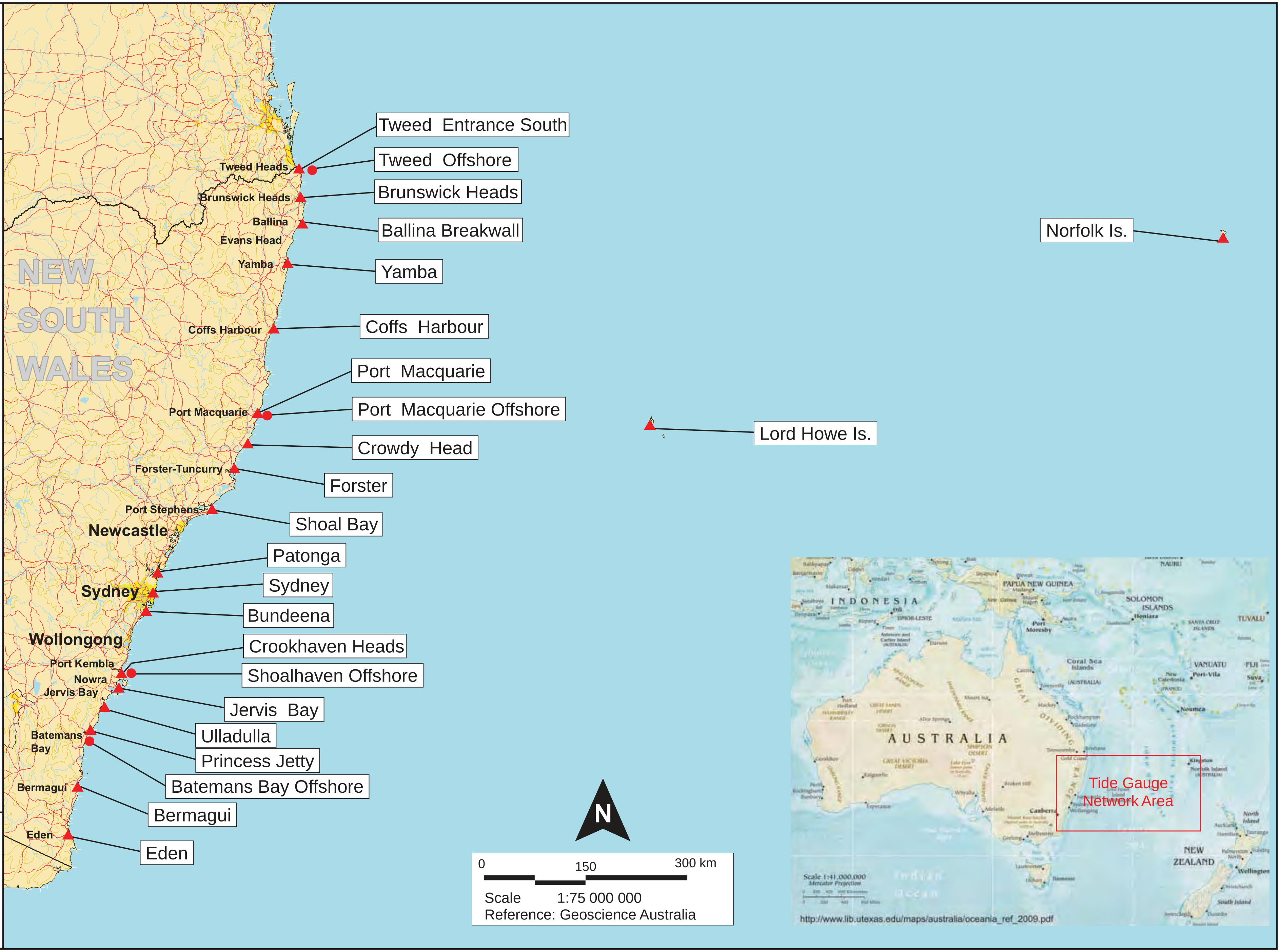
- Radar sensors: the water level is detected by radio waves detection and ranging technology. The data recorded is transferred via an Internet Protocol (IP) link through a modem between the data logger and the data server. As the data is a direct measurement of the water surface level, it requires no correction for barometric pressure. The system is shown in Figure 1.2.
- Vented pressure sensors: the water level is determined by a vented pressure sensor and recorded on a data logger. The sensor is vented to atmospheric pressure and therefore requires no correction for barometric pressure changes. The data recorded is transferred via an IP link through a modem between the data logger and the data server. The system is shown in Figure 1.3.
- Submersed water level recorder: the water level is determined by an absolute pressure sensor sealed in a waterproof housing and mounted on the ocean bed. The data requires post-recording correction for water density and barometric pressure changes. The data is downloaded manually from the recorder to MHL's data server after recovery from the ocean bed by divers. The system is shown in Figure 1.4.

Tidal data is transferred to the NSW Government Data Centre and to MHL's data server using an internet protocol (IP) network and landline telephone (Lord Howe Island). The 15-minute tide data is available online in tables or as plots. One-minute and some one-second data is also available on request (see Table 4.2 and Appendix D, Figure D1). All data presented in this report are in Australian Eastern Standard Time (AEST). Allowance for daylight saving time needs to be made by the user of the data if required.

The data is stored in a database and subject to a quality assurance process which involves several control steps to ensure data quality is maintained, as well as assignment of data quality codes. Computer programs are used to further format and analyse data. The database is backed up daily and data archived to offline storage at regular intervals.

The station locations and data summaries for 2019–2020 are presented in Appendix A.

Details of current sites available in a digital format are catalogued in Appendix B. Appendix C contains a list of historical data available in various formats and locations.



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OCEAN TIDE GAUGE NETWORK

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Figure

1.1

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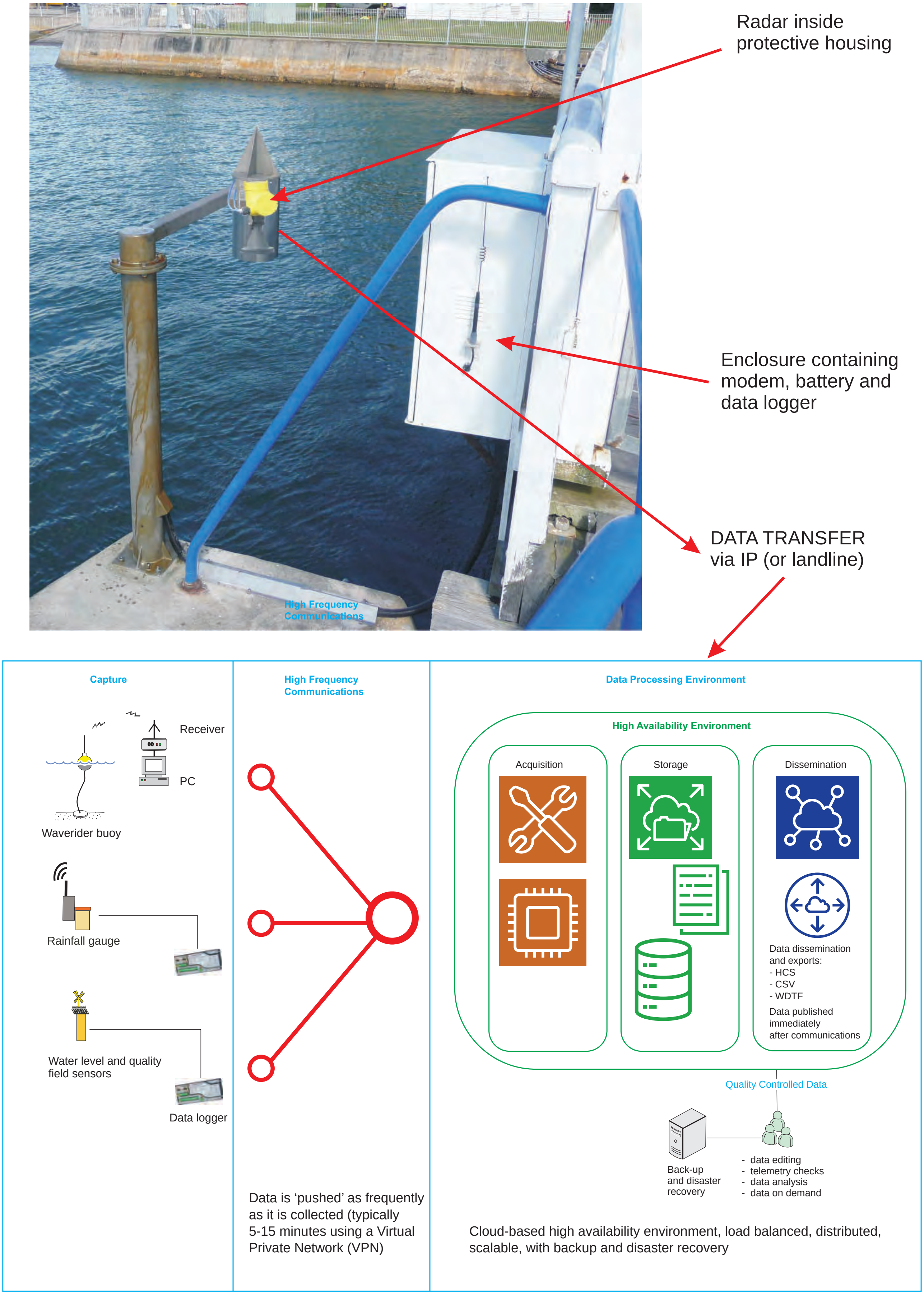

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RADAR SENSOR

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Figure

1.2

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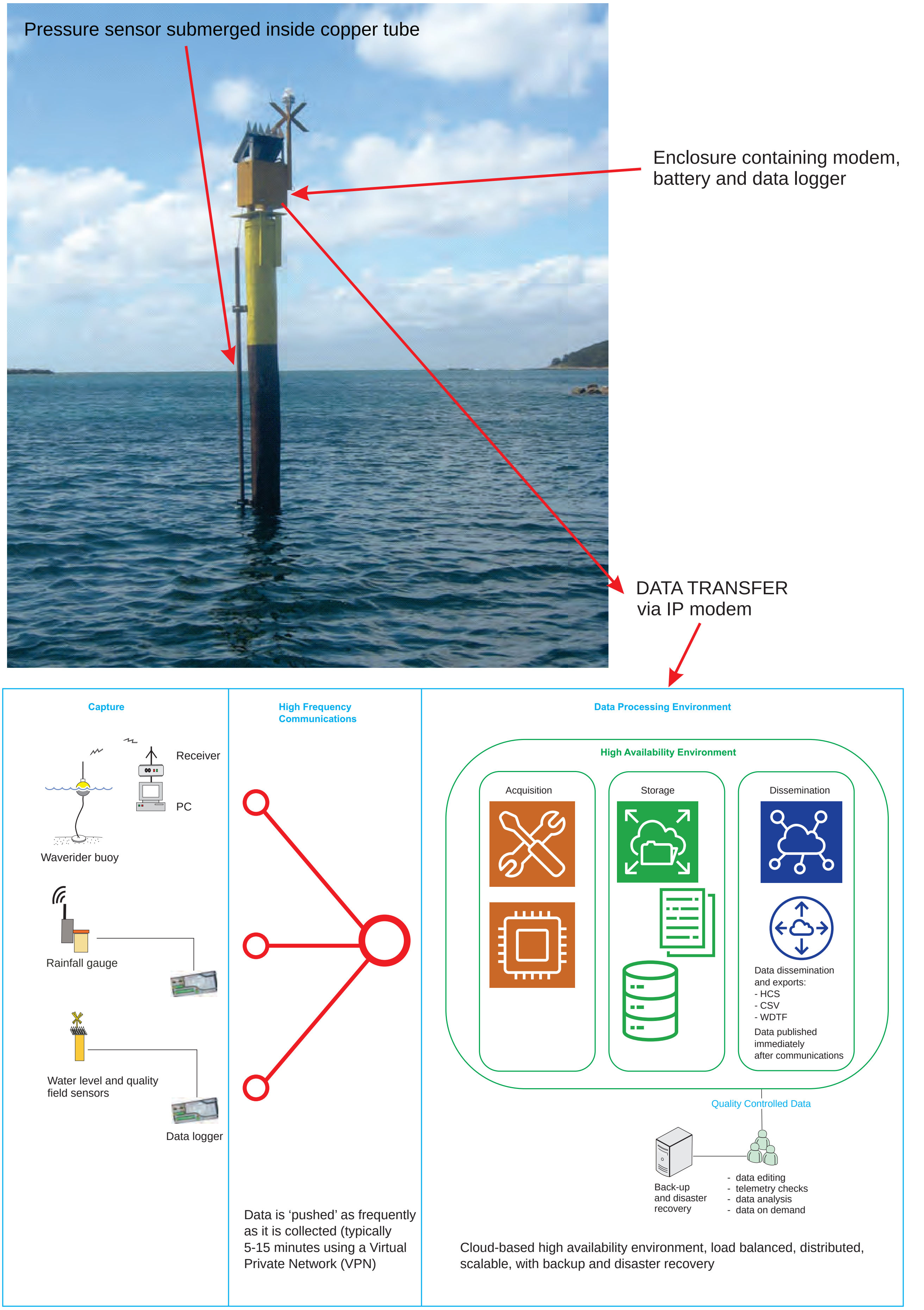

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VENTED PRESSURE SENSOR

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Figure 1.3

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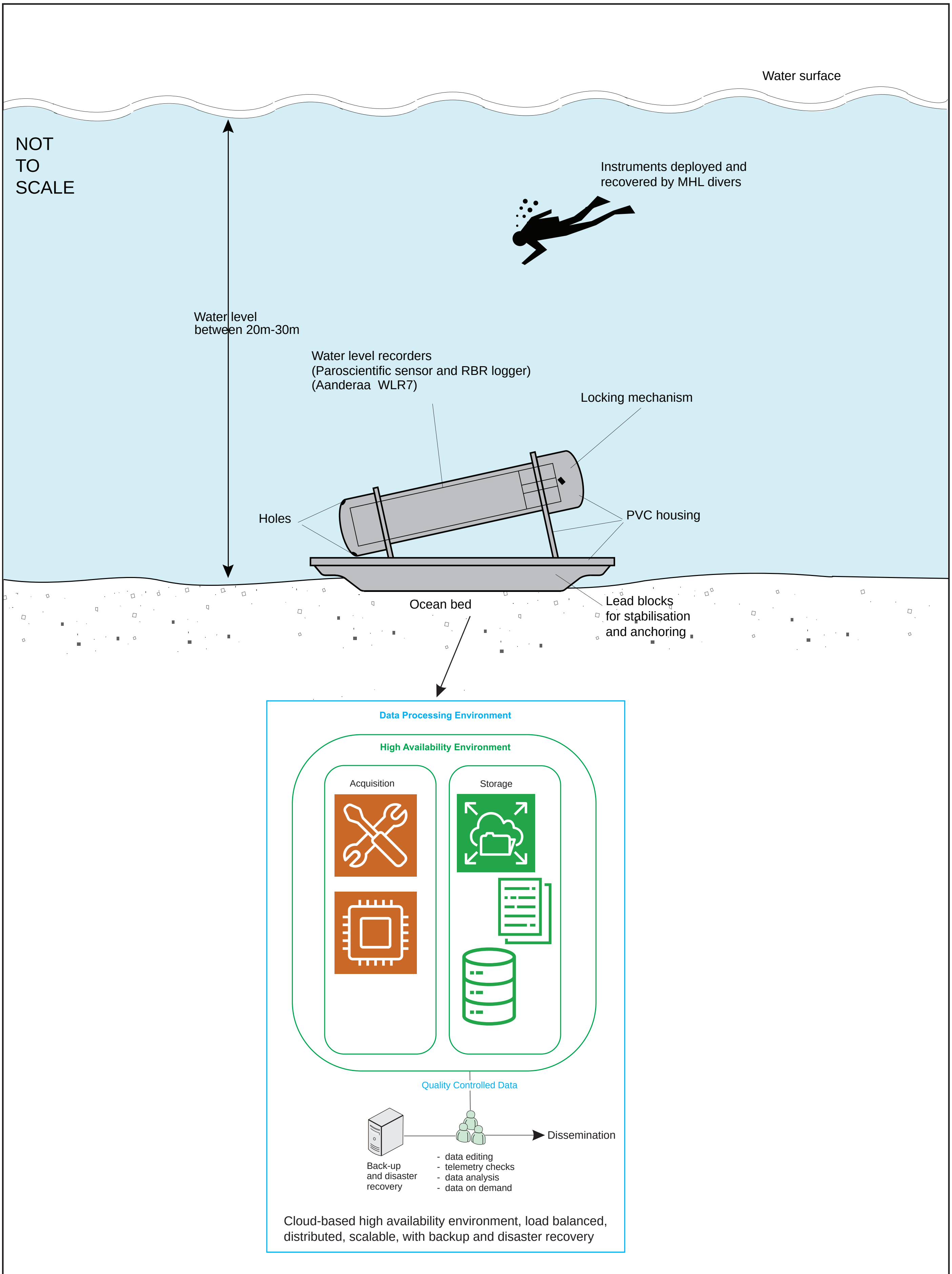

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SUBMERSED WATER LEVEL RECORDER

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Figure 1.4

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2. How to use this report

2.1 Using and accessing the data

This annual summary presents ocean and river entrance tidal data captured by the automatic tide level recording stations along the coastline of NSW over the period 1 July 2019 to 30 June 2020. The stations are located offshore, in bays, harbours and the entrances of major rivers.

To establish if data is available, first identify the relevant station on the ocean tide gauge network map (Figure 1.1), then refer to the relevant figure for that station. A location map of each station and a plot of the data from that station are provided in Appendix A. The plot confirms the availability of data for the fiscal year 2019–2020. For the availability of historical data which has been collected, refer to Appendices B and C.

Once a selection of data has been made the analysis and/or presentation can be obtained in a variety of formats. Appendix D shows samples of the following options: graphical plots (Figure D1), time series data (Figure D2), tidal analyses (Figure D3), tidal level ranking (Figure D4) and tidal predictions (Figure D5).

MHL provides a full on-line data access service via the internet for its clients, and a restricted service for the general public at http://www.mhl.nsw.gov.au.

Typically, the last seven days of data are available online in a non-quality-controlled form to aid quick access to raw data records. The on-line service for clients can provide access to all data catalogued in Appendices B and C, including tidal predictions. This data consists of tide levels and can be reviewed in graphical or numerical format shown in Appendix D.

Quality controlled data may be ordered via the MHL web page (http://www.mhl.nsw.gov.au), by emailing data-request@mhl.nsw.gov.au, or via customised decision support tools that can be provided on request.

2.2 Station location terminology

Tidal station locations can be referred to in several ways. As described in Appendix B, each station has a regional context (NSW coastal region), a catchment or port context (river catchment or port), a site context (specific locality, river port, harbour) and a specific location context (absolute location, e.g. on a specific jetty, bank of one side of the river, on a breakwater). Each context description of the location may be useful at different times, depending on what aspect of the data is being considered. The specific latitude and longitude details of stations are distributed as part of the metadata on request. In this report, the station name, as shown in Table B1, has been used throughout the report to avoid any naming convention confusion. The only exception is where references to other work are made, in which case the naming convention of the original author(s) is retained.

2.3 Datums

Most ocean tide water levels are recorded in the local port datum which generally equates to Indian Spring Low Water (ISLW). An indicative adjustment of each station from Australian Height Datum (AHD) to local port datum is shown in Table 2.1. Low water datums were calculated circa 1990 for MHL by NSW Public Works Survey, using range ratio method and tidal harmonic analysis over varying time periods. AHD values should be used with caution, as AHD levels are revised from time to time and improvements to surveying techniques may provide additional refinement.

Offshore sites are not related to a datum, but are adjusted by harmonic analysis to the Mean Sea Level (MSL) of each instrument deployment. They provide valuable astronomical constituent and anomaly information. There is no AHD survey information available for Norfolk Island and Lord Howe Island. The survey information for these two stations relates to the local datums.

Table 2.1 Summary of adjustment from AHD to local port datum

Station	Station datum (SD)	Adjustment (SD = AHD + Adjustment)
Tweed Entrance South	Tweed River Hydro Datum	0.893
Tweed Offshore	Mean Sea Level	N/A
Brunswick Heads	Brunswick River Flood Mitigation Datum	0.024
Ballina Breakwall	Richmond River Valley Datum	0.860
Yamba	Iluka Port Datum	0.895
Coffs Harbour	Coffs Port Datum	0.882
Port Macquarie	Australian Height Datum	0.000
Port Macquarie Offshore	Mean Sea Level	N/A
Crowdy Head	Crowdy Head Datum	0.911
Forster	Forster Hydro Datum	1.061
Shoal Bay	Port Stephens Hydro Datum	0.944
Patonga	Australian Height Datum	0.000
Sydney	Zero Fort Denison	0.925
Fort Denison (Sydney Ports)	Zero Fort Denison	0.925
Bundeena	Zero Fort Denison	0.925
Crookhaven Heads	Australian Height Datum	0.000
Shoalhaven Offshore	Mean Sea Level	N/A
Jervis Bay	Chart Datum	1.070
Ulladulla	Australian Height Datum	0.000
Princess Jetty	Australian Height Datum	0.000
Batemans Bay Offshore	Mean Sea Level	N/A
Bermagui	Bermagui Local Hydro Datum	0.714
Eden	Twofold Bay Hydro Datum	0.924
Lord Howe Island	Lord Howe Island Hydro Datum	Not available
Norfolk Island	Lowest Astronomical Tide	Not available

Data for Norfolk Island since 2015 provided by Bureau of Meteorology's National Tidal Unit (NTU).

2.4 Tidal planes and tidal forecasts

MHL uses the Foreman (1977) method to calculate the significant tidal constituents and tidal planes from data recorded at the ocean tide sites. From these tidal planes, MHL investigated the tidal ranges at NSW ocean tide sites (MHL 2005) and concluded that there is a general trend of increasing tidal range from south to north, however, there may be local variations to this trend. Nearshore sites located in river entrances displayed total ranges lower than the closest offshore sites, suggesting that the river entrances attenuate the tide as it progresses into the estuaries. Figure 2.1 shows this variation in graphical form by grouping the yearly mean ranges in geographical regions.

In 2012, a further analysis of tidal planes was completed for 188 MHL water level stations including the ocean tide stations (MHL 2012).

It is important to recognise tidal plane and constituent variations when applying data from the ocean tide sites. Variations between sites may significantly influence investigation outcomes. For example, the difference between the sites when used as the boundary conditions for numerical hydrodynamic models may significantly influence the model results. Such variations between sites reinforce the importance of the data being used in a manner which is fit for the purpose it is intended.

A long-term forecast was produced in 2015 for each ocean tide site for the full data range of historical data and predicted to 2020. The methodology determined the average of the yearly constituent values and then converted them to a single average phase and amplitude value (including Z_0 or MSL). The new constituent values were used to predict tidal forecasts up to 2020 (using the Foreman analysis). From these forecasts, the Highest Astronomical Tide (HAT) and Lowest Astronomical Tide (LAT) were determined for the tidal datum epoch (1995 to 2014). HAT, LAT and mean sea level (MSL) values were calculated to local low water datums, as well as to AHD, as shown in Table 2.2.

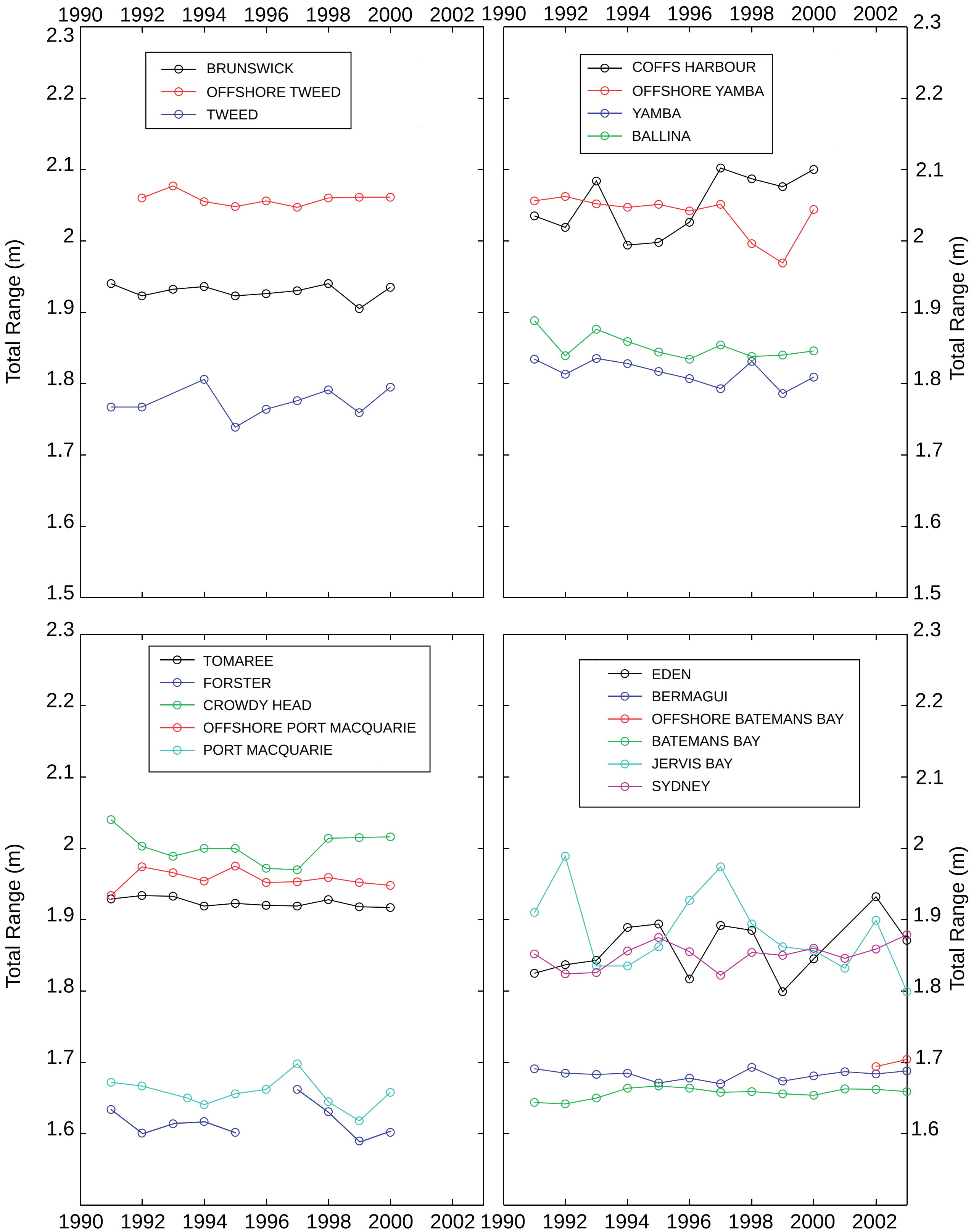
Table 2.2 Ocean and river entrance tide HAT and LAT values

Site	Period 1995–2014				Range (HAT-LAT)	Period 1995–2014	
	HAT^	LAT^	HAT (AHD)*	LAT (AHD)*		MSL	MSL (AHD)*
Tweed Heads	1.99	0.02	1.10	-0.87	1.97	0.93	0.04
Brunswick Heads	1.22	-0.85	1.17	-0.90	2.07	0.07	0.02
Ballina Breakwall	2.02	0.04	1.16	-0.82	1.98	0.89	0.03
Yamba	2.01	0.07	1.12	-0.83	1.94	0.95	0.05
Coffs Harbour	2.12	-0.11	1.24	-0.99	2.23	0.9	0.02
Port Macquarie	1.04	-0.74	1.04	-0.74	1.78	0.02	0.02
Crowdy Head	2.1	-0.09	1.19	-1.00	2.19	0.88	-0.03
Forster	1.93	0.17	0.87	-0.89	1.76	1.03	-0.03
Tomaree (Port Stephens)	2.08	-0.03	1.14	-0.97	2.11	0.92	-0.02
Patonga	1.16	-0.88	1.16	-0.88	2.04	0.06	0.06
Sydney	2.07	0.03	1.15	-0.90	2.04	0.96	0.03
Port Hacking	2.11	0.09	1.19	-0.84	2.02	1.00	0.08
Crookhaven Heads	1.01	-0.08	1.01	-0.08	1.09	0.03	0.03
Jervis Bay	2.19	0.10	1.12	-0.97	2.09	1.09	0.02
Ulladulla	1.20	-0.90	1.20	-0.90	2.10	0.05	0.05
Princess Jetty	1.06	-0.79	1.06	-0.79	1.85	0.06	0.06
Bermagui	1.72	-0.18	1.01	-0.89	1.90	0.69	-0.02
Eden	1.92	-0.11	1.00	-1.03	2.03	0.84	-0.08
Lord Howe Island	2.35	-0.06	n/a	n/a	2.41	1.10	n/a
Norfolk Island	1.97	0.03	n/a	n/a	1.94	0.97	n/a

* Conversion from AHD to local port datum given in Table 2.1

^ Local port datum

Data for Norfolk Island since 2015 provided by Bureau of Meteorology's National Tidal Unit (NTU).



Notes: Each offshore gauge has been grouped with the closest nearshore gauges for comparison

Total range defined by: tidal plane formula = HHWSS – ISLW

or by: tidal constituent formula = $2(M_2 + S_2 + 1.2K_1 + 1.20_1)$

Forster 1996 tidal range value is not calculated due to a high proportion of poor data during that financial year.

Source: MHL 2005

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TIDAL RANGE FOR GROUPED OFFSHORE AND NEARSHORE GAUGES 1990–2003

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Figure 2.1

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3. Significant events 2019–2020

The data recovery statistics are shown in Table 3.1.

Table 3.1 Data recovery July 2019 to June 2020

Data stream	Data recovery (%)	Comments
15-minute ocean tide data	99.5	Ballina Breakwall – continuing issues with siltation build-up inside conduit causing delayed flushing and introducing a phase lag in the monitored values. Attempts to dive on site this year and extend the orifice length were unable to proceed due to poor conditions. Shoal Bay – Radar conduit cable ripped out below wharf causing radar to fail. Cable and conduit were replaced. Level 2 15-minute data was imported into the Level 1 15-minute time series but could not be imported to the 1-minute time series.
1-minute ocean tide data	97.5	
5-minute and 60-minute offshore data	90.0	The RBR logger at Port Macquarie had water ingress or battery leak, all data was lost and the logger destroyed. The backup Aanderaa recovered 59% of the data before siltation of the sensor caused the remaining data to be lost.

The 2021 NSW Tide Prediction Charts are available free of charge via download from the MHL public web page. The charts remain an authoritative reference for tides along the NSW coast (Figure 3.1). As for previous tide prediction publications, MHL adopts the Sydney tide gauge as the primary reference station, and the ocean tide predictions for NSW are based on an analysis of 15–minute tide levels recorded by this primary gauge. The time difference between the primary and secondary locations in NSW was obtained through analysis of the tide levels recorded at gauges at each of the secondary locations (MHL 2001).

3.1 Tidal anomalies

Tidal anomalies in this report are calculated as the difference between the recorded data and the long-term epoch forecasts as discussed in Section 2.4.

The main drivers of anomalies are barometric pressure, wind setup, coastally trapped waves, and the influence of the East Australian Current (EAC). For onshore river entrance gauges, hydrological anomalies such as floods can also occur. Storms are usually associated with large barometric pressure changes and wind setup. The types of large scale storms affecting NSW include East Coast Lows (ECL) and the effects of tropical cyclones off the Queensland coast. Furthermore, tsunamis can cause waves that present on the onshore open ocean and onshore bay or port gauges as tidal anomalies.

The NSW Extreme Ocean Water Levels report (MHL 2018) investigated anomalies recorded on the NSW coast and considered their occurrence and forcing mechanisms.

The anomalies recorded on the NSW coast during the reporting period are compared across a selected group of stations in Figure 3.2. The major anomalies, which are classified as greater than ±0.2 m difference between recorded and forecast data, are identified on Figure 3.2 and documented in more detail in Figures 3.3 and 3.4. Most are driven by ECLs or large high pressure systems. Figures 3.5–3.8 show the tidal anomalies recorded at each station during the reporting period. Figure 3.9 shows the anomalies for the four offshore tide stations.

The Bureau of Meteorology (BoM) recorded one Tropical Low and one Tropical Cyclone in North Queensland during the 2019–2020 reporting period:

- 4 to 14 February 2020, Tropical Cyclone Uesi formed east of the Solomon Islands and tracked south where it peaked at intensity off New Caledonia. Ex-Tropical Cyclone Uesi continued tracking south down the eastern seaboard of Australia whilst being downgraded to a tropical low. Figure 3.10 shows the BoM tracking of Tropical Low Uesi passing directly over Lord Howe Island. Although downgraded, Tropical Low Uesi maintained Category 2 cyclone equivalent wind strengths with a maximum gust of 124 km/h recorded at Lord Howe Island Airport. There was a direct impact on the tidal trace at the Lord Howe Island gauge raising the tidal anomaly to above 0.4 m on 14 February 2020 attributed to the wave setup as shown in Figure 3.10. Residual effects of Tropical Low Uesi were also felt on NSW onshore coastlines with large swell measured on the north coast as the Byron Bay Waverider buoy recorded a maximum wave height of over 9 m on 14 February 2020 (Figure 3.10).
- 10 to 15 March 2020, Tropical Cyclone Gretel – Category 1 – developed as a Tropical Low in the Gulf of Carpentaria before crossing over northern Queensland and continuing on a predominately westerly track before strengthening into a tropical cyclone off New Caledonia. The direction of travel meant tidal impacts on the east coast were minimal, with only a small tidal residual effect from Tropical Cyclone Gretel recorded on the NSW north coast ocean tide gauges created by the associated long period easterly swell.

3.2 Tsunami events

Table 3.2 lists the tsunami events in the Pacific Region for the period of time corresponding to the 2019–2020 data in this report.

Table 3.2 Recorded earthquake events July 2019 to June 2020

Date	Earthquake magnitude (M_W)	Location	Observable on NSW tide recordings
14/11/2019	7.1	Indonesia – N. Moluccas Island	No
18/06/2020	7.4	New Zealand – Kermadec Islands	No

Source: NOAA National Geophysical Data Centre Tsunami Database http://www.ngdc.noaa.gov/hazard/tsu.shtml

The BoM and Geoscience Australia host the Joint Australian Tsunami Warning Centre (JATWC). No tsunami warnings were issued by JATWC from July 2019 to June 2020. The BoM collects specific tsunami data for issuing warnings, and the data can be requested from BoM for further use.

3.3 King tide events

Predicted king tides over the 2019–2020 financial year occurred on 2 August 2019, 10 February 2020 and 6 June 2020. The highest recorded actual water level associated with a king tide in Sydney was 1.08 m AHD in June 2020.

The highest water level recorded at the Sydney gauge during the 2019–2020 financial year occurred on 24 May 2020 measuring 1.25 m AHD. This was during a spring high tide, which coincided with a large south coast low pressure system. This low pressure system raised water level residuals along the entire NSW coast, as highlighted in Figure 3.4.

3.4 High wind seiche event

High water levels due to coastal events can be exacerbated by winds which cause setup and setdown at opposite ends of the water body. A wave setup with a fixed boundary condition is called a seiche wave. The water level disturbance is essentially trapped as a standing wave and will continually propagate back and forward against the boundaries until it dissipates in energy. These unseen harmonic waves can have a significant impact on coastal infrastructure, harbours and inland waterways.

The weather event highlighted in Figure 3.4 and Figure 3.11 shows a synoptic time series of multiple low pressure systems moving off the Southern Ocean and combining into an extreme cold weather event across NSW. Consistent strong driving winds from the south-west provided a cumulative effect on ocean tide water levels. With the initial disturbance energy provided by the weather system a distinguished harmonic within the residual was picked up predominately in south coast ports and bay gauges as shown in Figure 3.12. The smaller harbours of Eden and Ulladulla had an amplified range of seiche wave compared to Jervis Bay which has a far greater area of enclosed water. There were less impacts on the mid-NSW coast with Sydney and Crowdy Head only showing a minimal disturbance by comparison. Figure 3.12 plots 1-minute and 1-second data sets over the prediction period during the peak of the seiche wave within Eden harbour showing the resonant wave clearly visible at the lower time resolution.

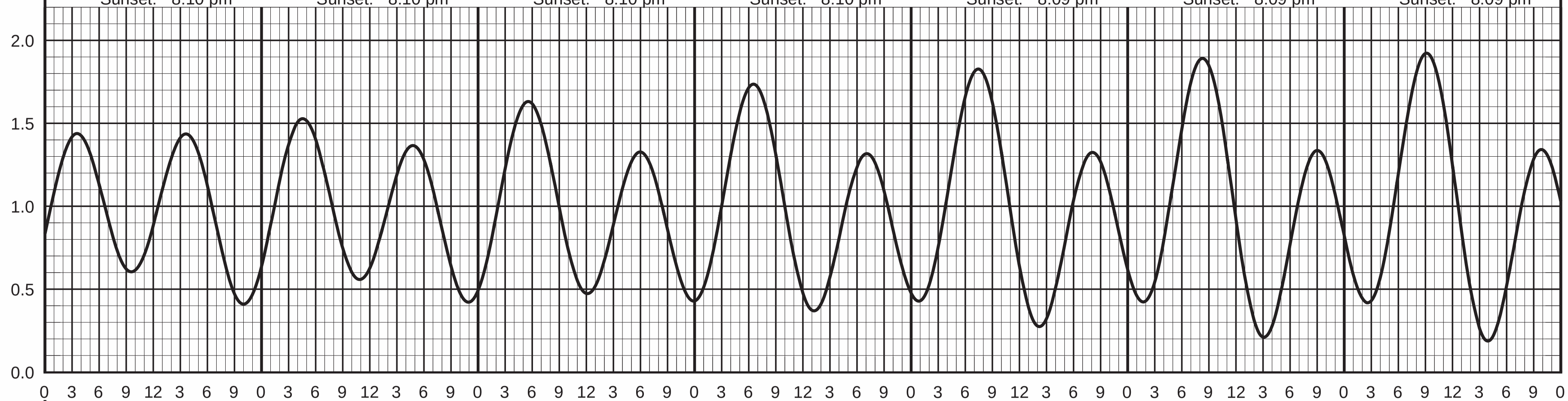
Both Ulladulla and Eden harbours contain commercial vessels and have local community industry attached to their infrastructure. Events such as these can damage property and vessels while also creating a safety hazard. The captured tidal data is valuable to assist understanding and modelling of harbour improvements to mitigate seiching effects, as MHL has previously assisted with in harbours such as Crowdy Head and Coffs Harbour.

January 7-13, 2021

Daylight Saving Time

New Moon Jan 13

7 THURSDAY	8 FRIDAY	9 SATURDAY	10 SUNDAY	11 MONDAY	12 TUESDAY	13 WEDNESDAY
Sunrise: 5:52 am Sunset: 8:10 pm	Sunrise: 5:53 am Sunset: 8:10 pm	Sunrise: 5:54 am Sunset: 8:10 pm	Sunrise: 5:55 am Sunset: 8:10 pm	Sunrise: 5:56 am Sunset: 8:09 pm	Sunrise: 5:57 am Sunset: 8:09 pm	Sunrise: 5:58 am Sunset: 8:09 pm



7 THURSDAY		8 FRIDAY		9 SATURDAY		10 SUNDAY		11 MONDAY		12 TUESDAY		13 WEDNESDAY	
3:33am	**1.44m 4ft 9in**	**4:34am**	**1.53m 5ft 0in**	**5:33am**	**1.63m 5ft 4in**	**6:31am**	**1.74m 5ft 8in**	12:49am	0.43m 1ft 5in	1:44am	0.42m 1ft 5in	2:35am	0.42m 1ft 4in
9:35am	0.60m 2ft 0in	10:53am	0.56m 1ft 10in	12:07pm	0.47m 1ft 7in	1:14pm	0.37m 1ft 3in	**7:26am**	**1.83m 6ft 0in**	**8:18am**	**1.89m 6ft 3in**	**9:08am**	**1.92m 6ft 4in**
3:37pm	**1.44m 4ft 9in**	**4:47pm**	**1.37m 4ft 6in**	**5:58pm**	**1.33m 4ft 4in**	**7:05pm**	**1.32m 4ft 4in**	2:13pm	0.27m 0ft 11in	3:06pm	0.21m 0ft 8in	3:55pm	0.19m 0ft 7in
10:01pm	0.41m 1ft 4in	10:57pm	0.42m 1ft 5in	11:53pm	0.43m 1ft 5in			**8:06pm**	**1.33m 4ft 4in**	**9:01pm**	**1.34m 4ft 5in**	**9:51pm**	**1.34m 4ft 5in**

NSW GOVERNMENT

NSW TIDAL PREDICTIONS
EXTRACT FROM 'NSW TIDE CHARTS 2021'

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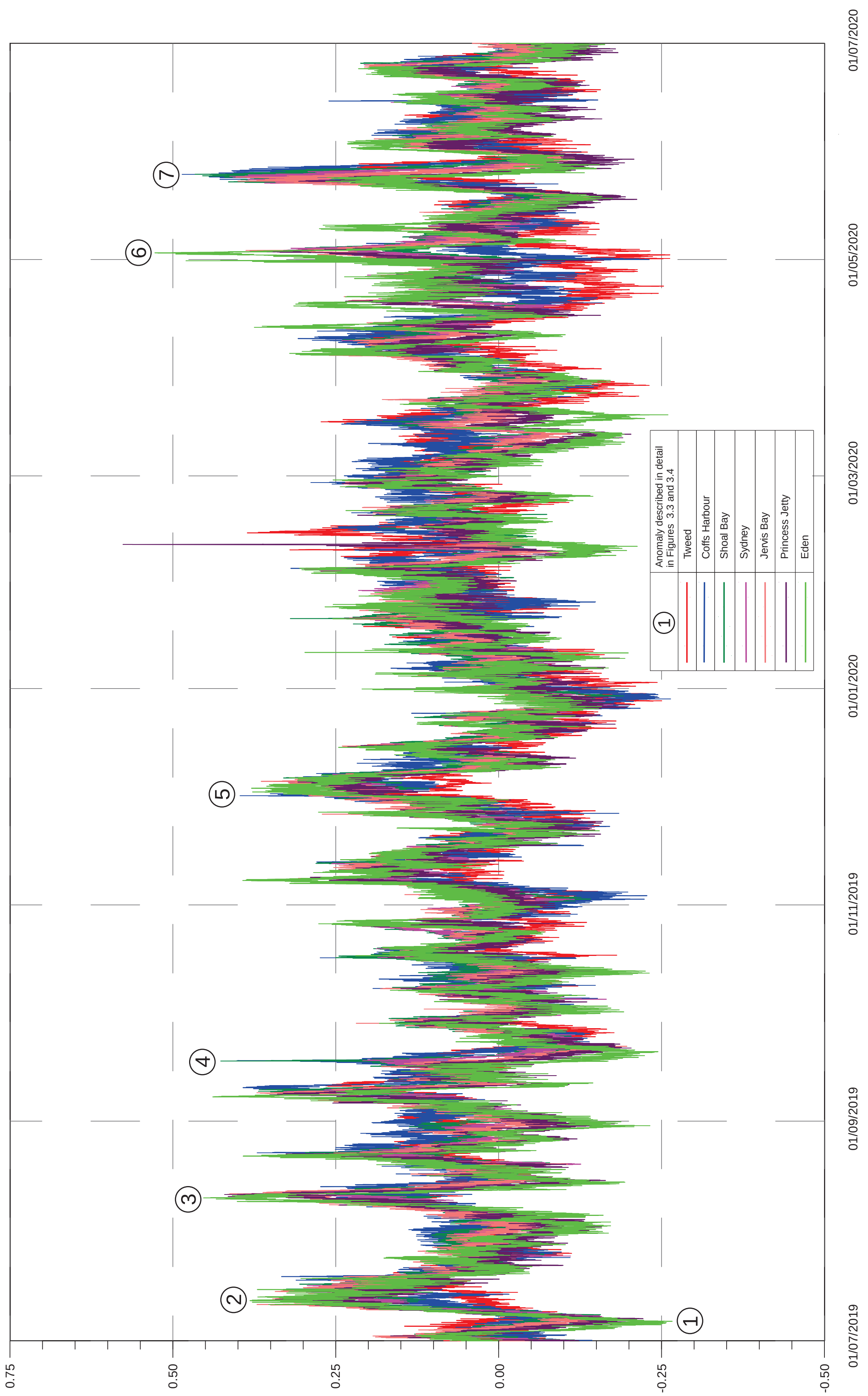
Figure 3.1

DRAWING 2770-03-01.cdr



NSW TIDAL ANOMALIES PLOT 2019–2020

Manly Hydraulics Laboratory

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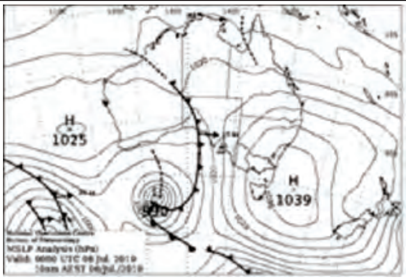
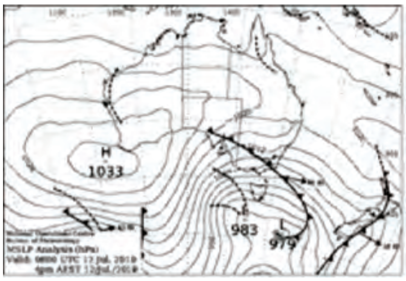
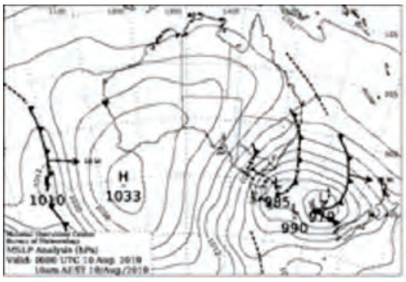
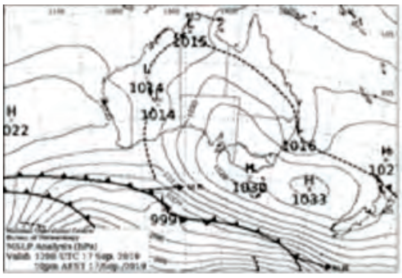
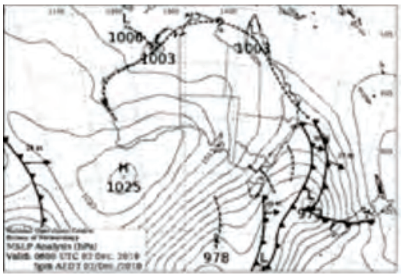
Figure 3.2

DRAWING 2770-03-02.cdr

Event Number (see Figure 3.2)	Event Period	BoM Weather Map*	Peak Anomaly	Sites where Anomaly > +/- 0.25m
1	05–07 July 2019	 Large high pressure system	Site Eden Date 060/7/2019 Time 1315 Peak Value -0.267	Ulladulla, Princess Jetty, Eden
2	11–19 July 2019	 Multiple sustained low pressure systems	Site Bermagui Date 12/07/2019 Time 1000 Peak Value 0.393	Ballina, Coffs Harbour, Crowdy Head, Forster, Shoal Bay, Patonga, Sydney, Bundeena, Crookhaven Heads, Jervis Bay, Ulladulla, Princess Jetty, Bermagui, Eden
3	09–13 August 2019	 South coast low pressure system	Site Eden Date 10/08/2019 Time 0830 Peak Value 0.453	Shoal Bay, Patonga, Sydney, Bundeena, Crookhaven Heads, Jervis Bay, Ulladulla, Princess Jetty, Bermagui, Eden
4	17–18 September 2019	 Localised east coast low	Site Shoal Bay Date 17/09/2019 Time 2315 Peak Value 0.426	Coffs Harbour, Crowdy Head, Forster, Shoal Bay
5	01–07 December 2019	 Multiple sustained low pressure systems	Site Patonga Date 05/12/2019 Time 1715 Peak Value 0.340	Coffs Harbour, Port Macquarie, Crowdy Head, Forster, Shoal Bay, Patonga, Sydney, Bundeena, Crookhaven Heads, Jervis Bay, Ulladulla, Princess Jetty, Bermagui, Eden

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TIDAL ANOMALIES JULY 2019–JUNE 2020

Manly Hydraulics Laboratory

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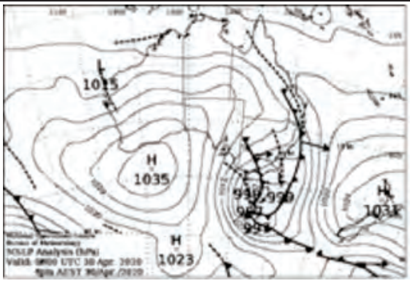
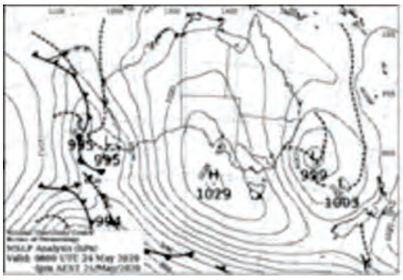
Figure 3.3

DRAWING 2770-03-03.cdr

Event Number (see Figure 3.2)	Event Period	BoM Weather Map*	Peak Anomaly	Sites where Anomaly > +/- 0.25m
6	30 April–03 May 2020	 Strong wind wave event into south coast low	Site Eden Date 02/05/2020 Time 2130 Peak Value 0.528	Crowdy Head, Forster, Shoal Bay, Patonga, Sydney, Bundeena, Crookhaven Heads, Jervis Bay, Ulladulla, Princess Jetty, Bermagui, Eden
7	23–27 May 2020	 East coast low	Site Patonga Date 24/05/2020 Time 1730 Peak Value 0.470	Tweed Heads, Brunswick Heads, Ballina, Coffs Harbour, Port Macquarie, Crowdy Head, Forster, Shoal Bay, Patonga, Sydney, Bundeena, Crookhaven Heads, Jervis Bay, Ulladulla, Princess Jetty, Bermagui, Eden

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TIDAL ANOMALIES JULY 2019–JUNE 2020

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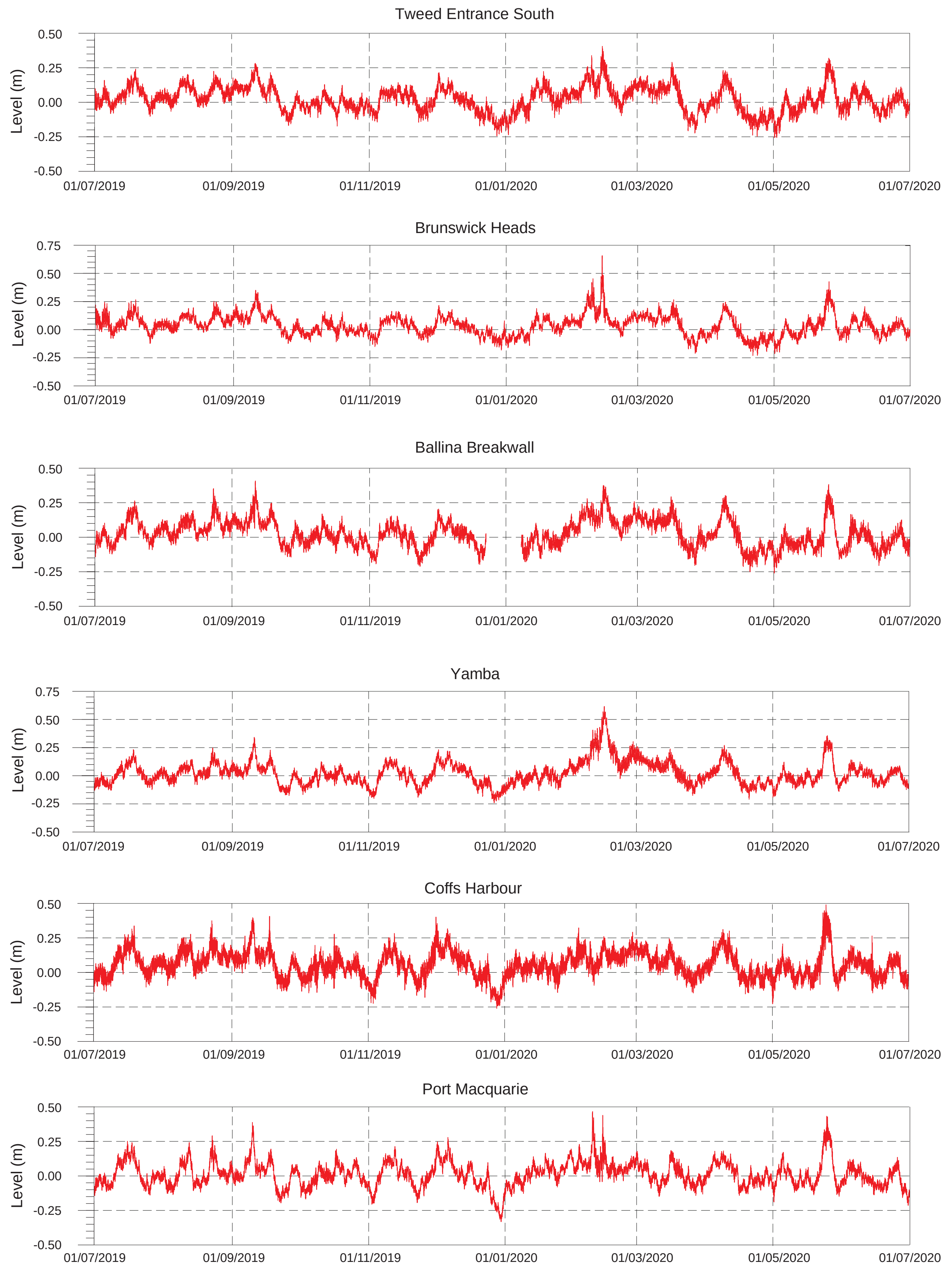
Figure

3.4

DRAWING 2770-03-04.cdr



TIDAL ANOMALIES 2019–2020
TWEED ENTRANCE SOUTH TO PORT MACQUARIE

NSW GOVERNMENT

Manly Hydraulics Laboratory

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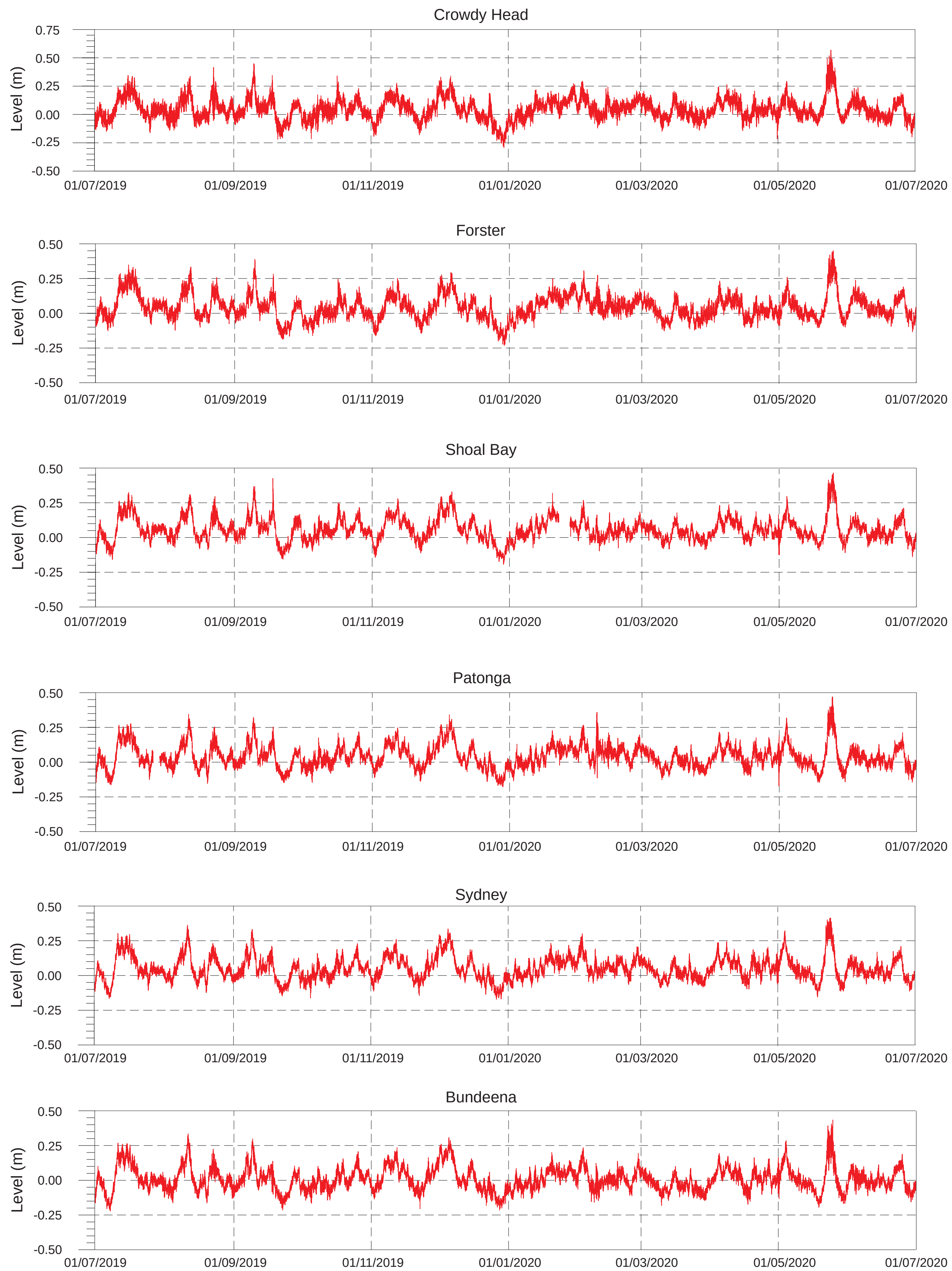
Figure 3.5

DRAWING 2770-03-05.cdr



TIDAL ANOMALIES 2019–2020
CROWDY HEAD TO BUNDEENA

NSW GOVERNMENT

Manly Hydraulics Laboratory

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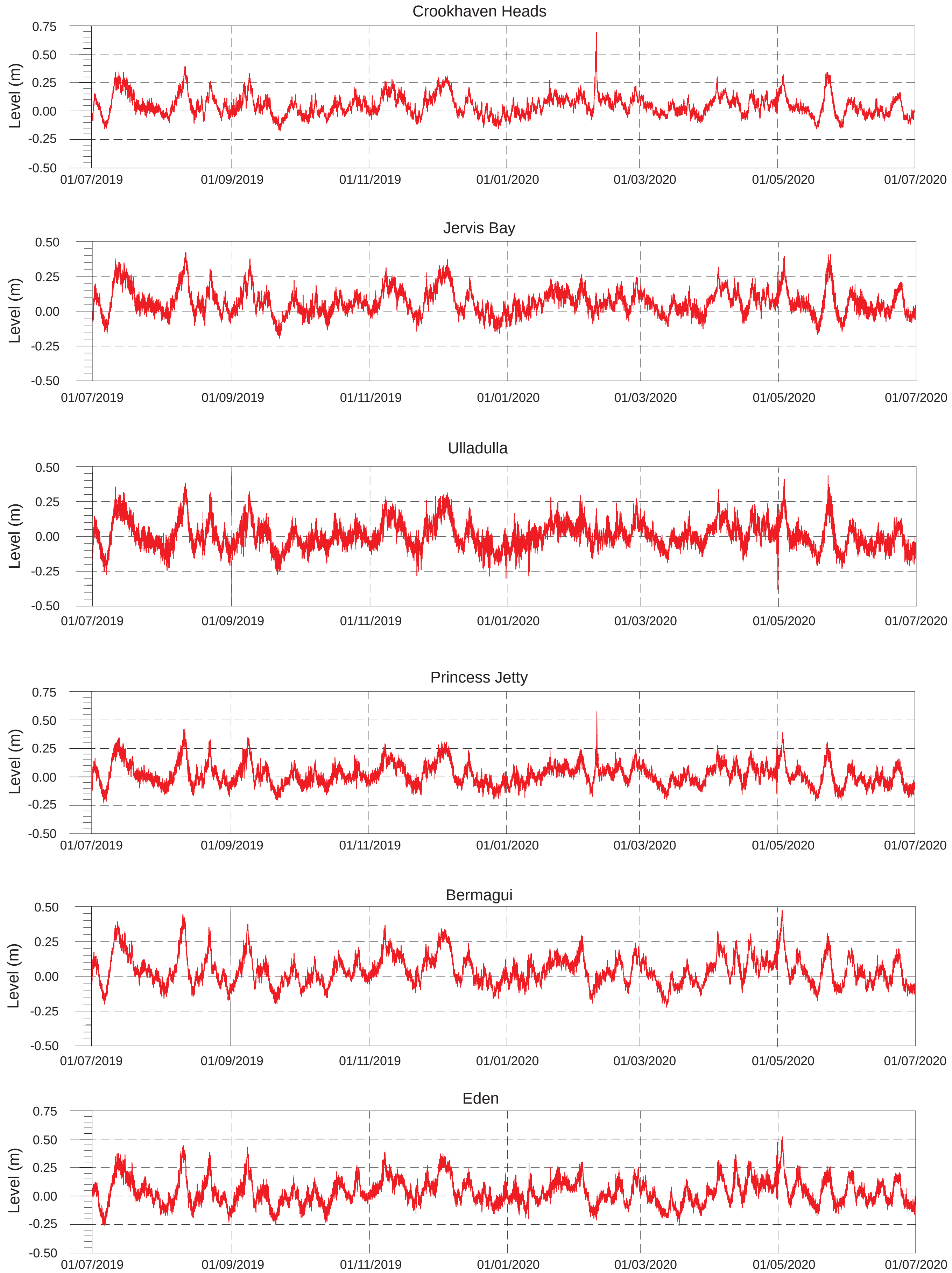
Figure

3.6

DRAWING 2770-03-06.cdr



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TIDAL ANOMALIES 2019–2020
CROOKHAVEN HEADS TO EDEN

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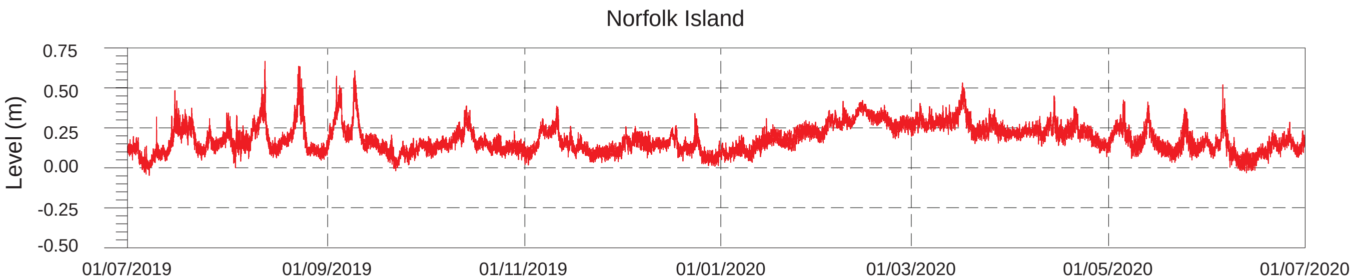
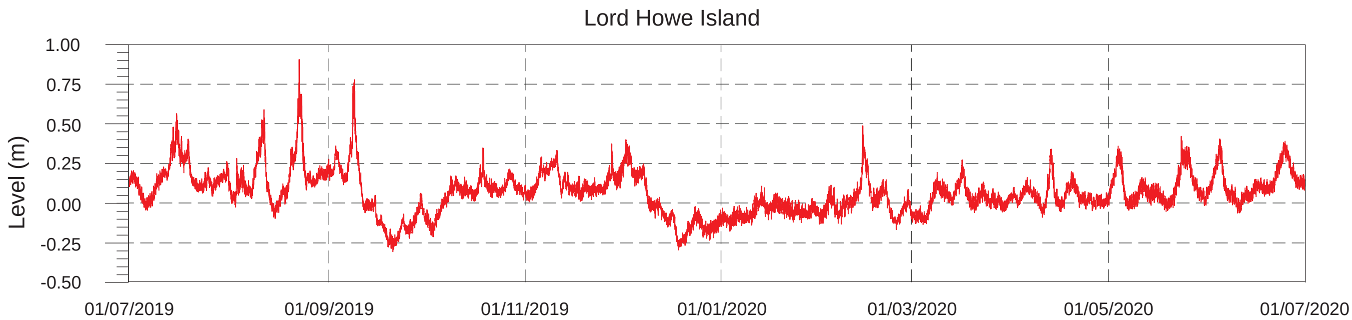
Figure
3.7

DRAWING 2770-03-07.cdr





Data for Norfolk Island provided by Bureau of Meteorology's National Tidal Unit (NTU)

NSW GOVERNMENT

TIDAL ANOMALIES 2019–2020
NORFOLK ISLAND AND LORD HOWE ISLAND

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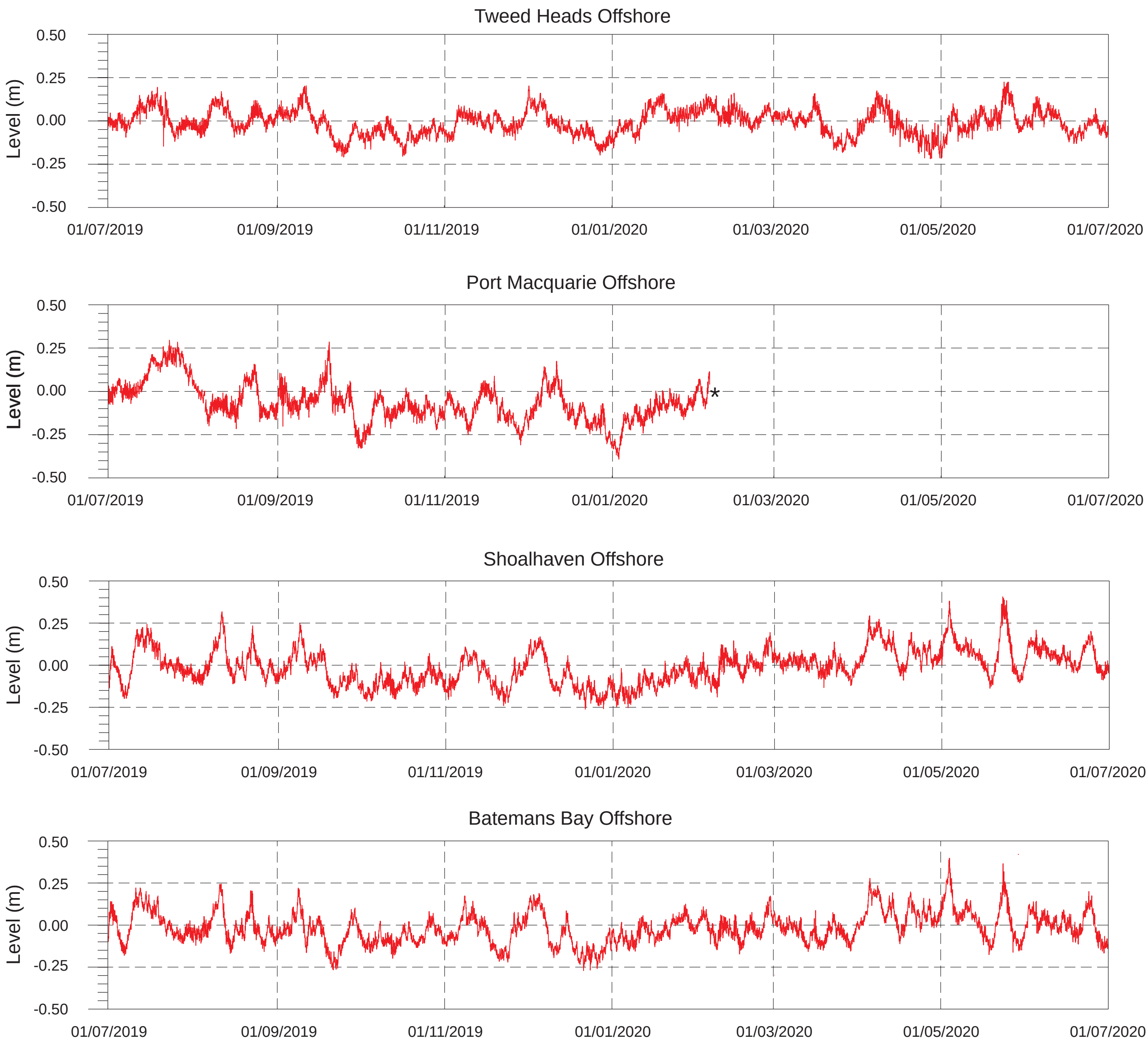
Figure

3.8

DRAWING 2770-03-08.cdr



* Data loss due to equipment failure

TIDAL ANOMALIES 2019–2020
OFFSHORE TIDE GAUGES

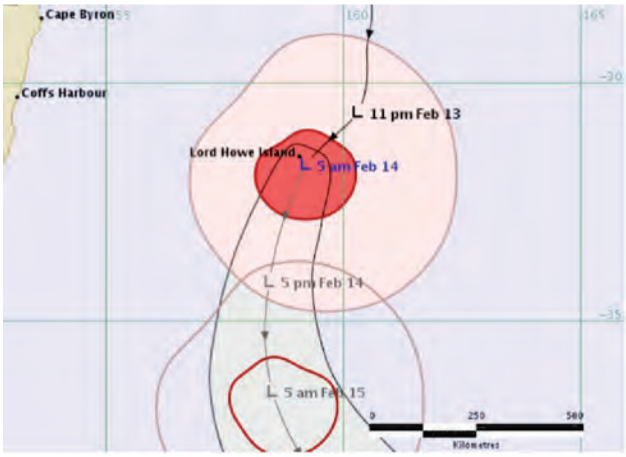
NSW GOVERNMENT

Manly Hydraulics Laboratory

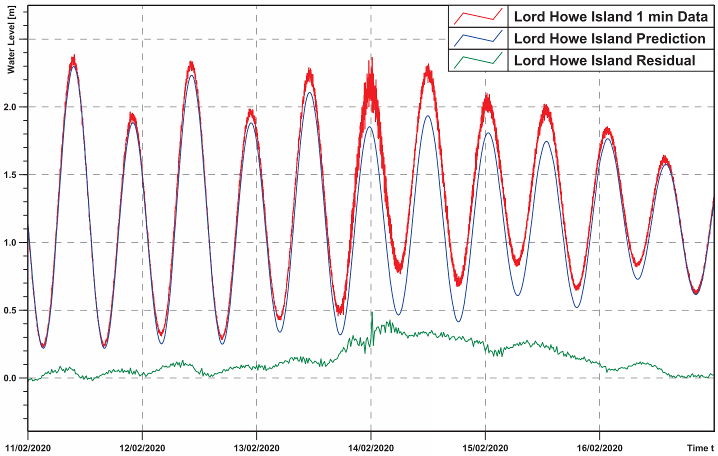
Report MHL2770

Figure 3.9

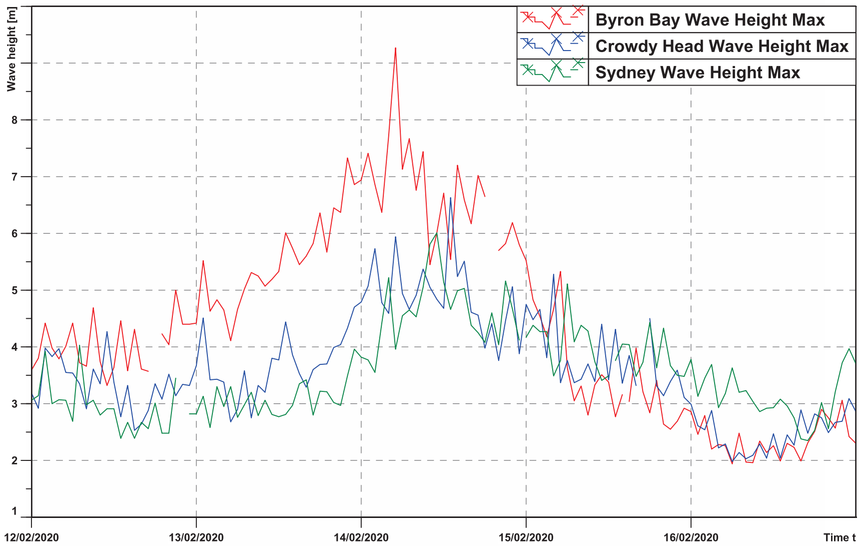
DRAWING 2770-03-09.cdr



Tropical Low Uesi tracking map, courtesy of BoM



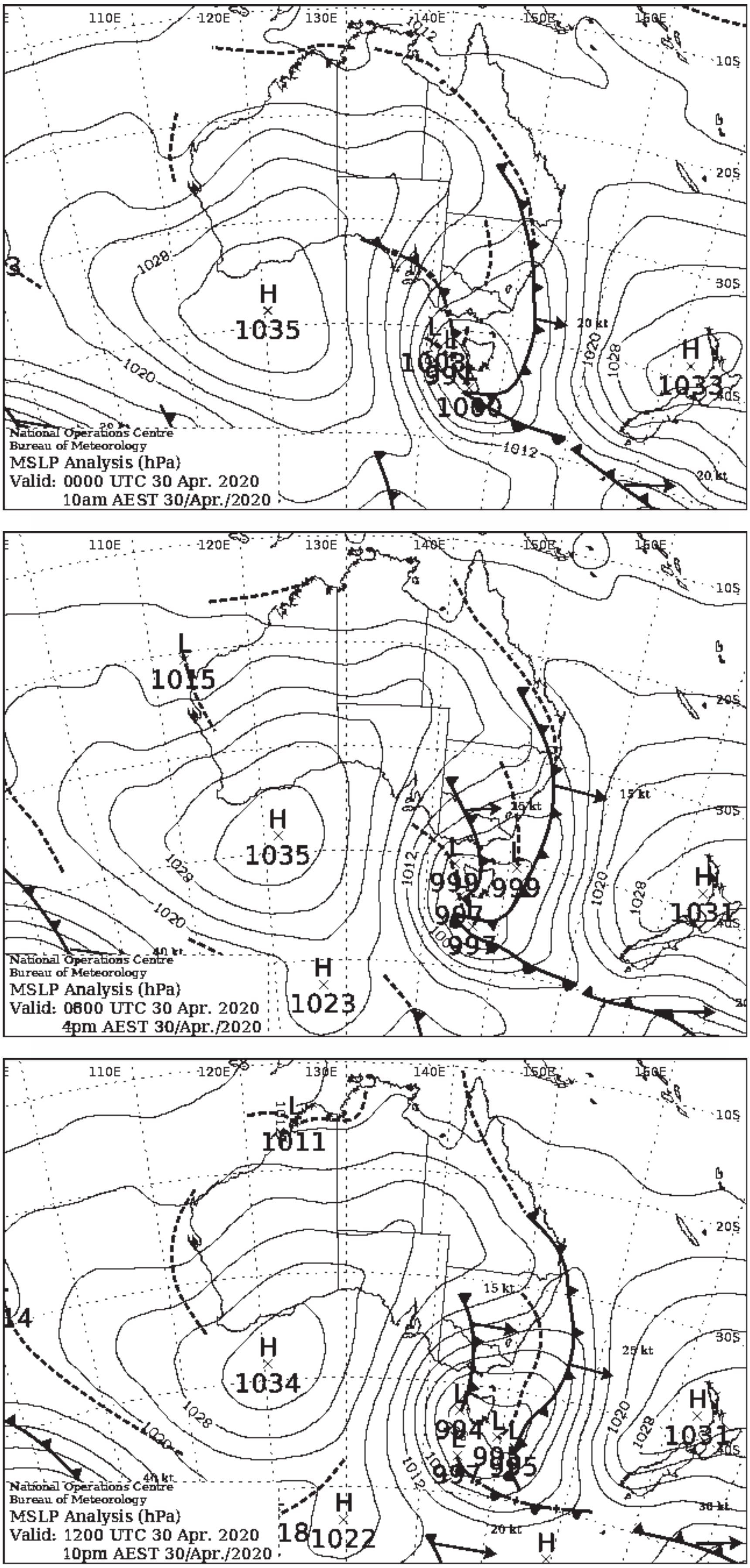
Lord Howe Island water levels



Onshore NSW Waverider buoy data during Tropical Low Uesi

Waves on Lord Howe Island during Tropical Low Uesi, courtesy ABC News

NSW GOVERNMENT	FEBRUARY 2020 TROPICAL LOW UESI EFFECTS ON LORD HOWE ISLAND	Manly Hydraulics Laboratory Report MHL2770 Figure 3.10 DRAWING 2770-03-10.cdr



Maps courtesy of Bureau of Meteorology, 2020

NSW GOVERNMENT

APRIL 2020 SYNOPTIC MAPS
FOR SOUTH COAST STORM EVENT

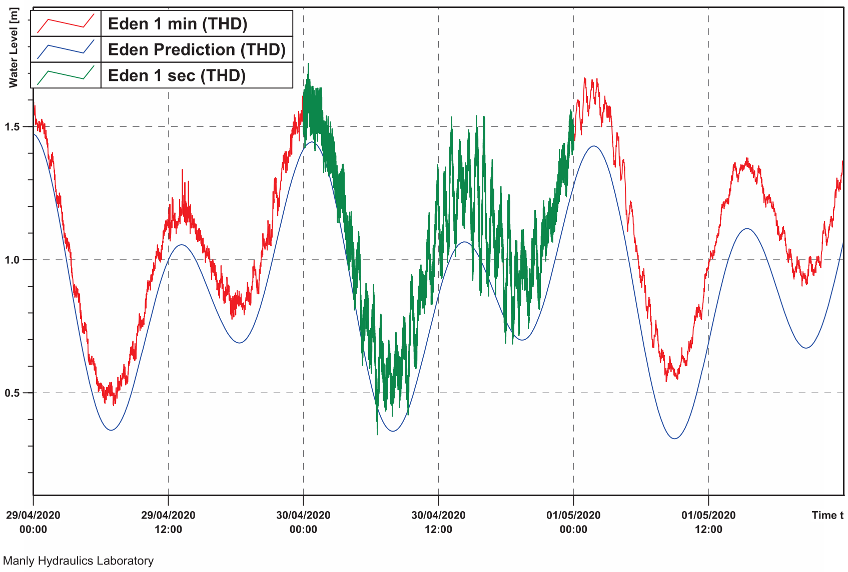
Manly Hydraulics Laboratory

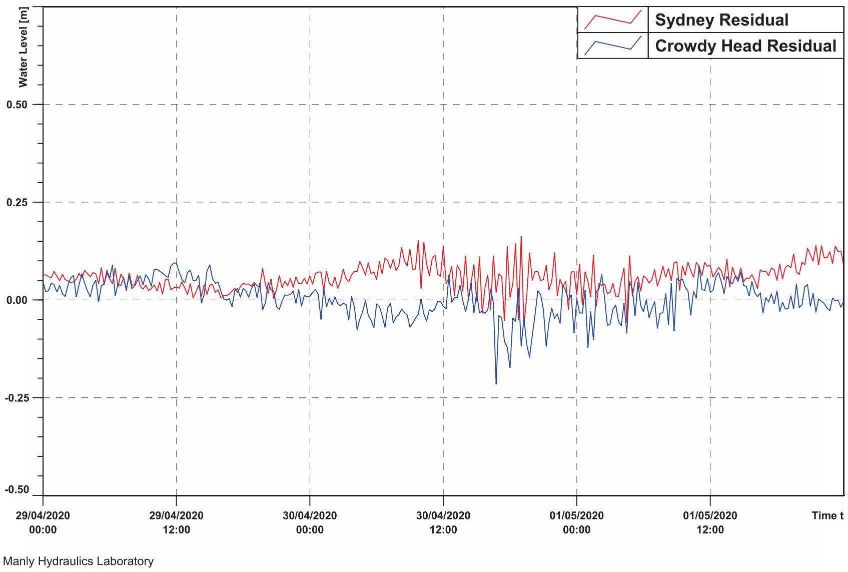
Report MHL2770

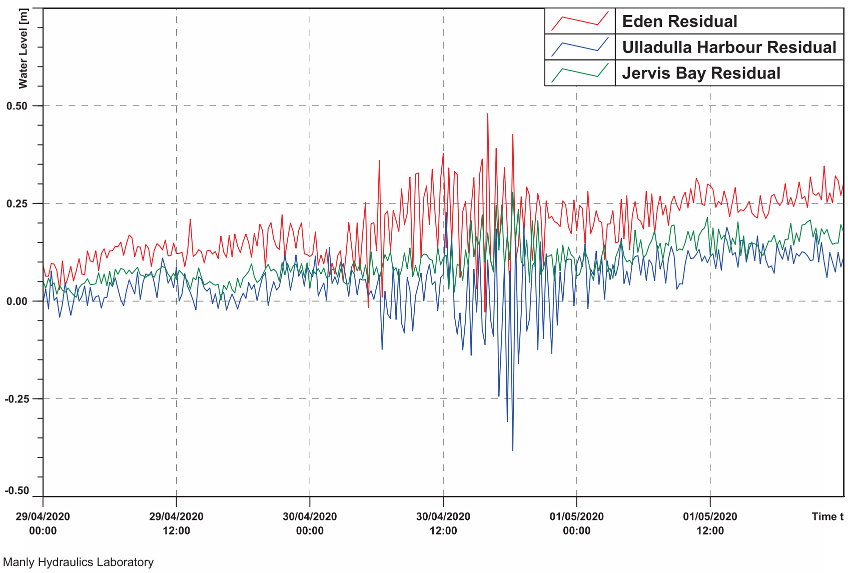
Figure

3.11

DRAWING 2770-03-11.cdr







NSW GOVERNMENT

WATER LEVEL RESIDUALS IN NSW HARBOURS DURING APRIL 2020 SEICHE EVENT

Manly Hydraulics Laboratory

Report MHL2770

Figure 3.12

DRAWING 2770-03-12.cdr

4. Program developments 2019–2020

4.1 Classification of stations

An increasing interest in sea level rise, tsunami and storm surge data has led to the adoption of a classification of each of the stations based on the type of data they represent from their recording location. As the ocean tide and river entrance program collects data from a variety of recording locations, from offshore sites to sites inside the entrances of rivers and inside ports, this classification of sites highlights to users the possible variability of data, based on recording location.

The classifications in order from river entrance to offshore are:

- Onshore river entrance – stations that are located within a river a short distance upstream of the entrance usually maintained open by training walls. Typically, these locations do not provide good representation of ocean water levels because they show a reduction of tidal range between 0.1 and 0.2 m compared to ocean tide, and may be affected by entrance conditions and floods.
- Onshore bay or port – bank or pole-mounted sensor located in an embayment or harbour. Effective at measuring the ocean water levels where there is no significant influence by floods. Can be influenced by harbour motions (i.e. seiches).
- Onshore open ocean – jetty or bank-mounted sensor located in an open ocean location. Effective at measuring the ocean water levels, but may have problems if located in the surf zone. Lord Howe Island is currently the only operating station in this category.
- Offshore open ocean – bottom-mounted sensors that are located between 2 and 5 km offshore of the coast generally in about 25 m depth of water. Very effective at measuring ocean water level but an accurate datum cannot be practically determined.

The classification indicates sites that are similar in their location and gives an indication to the end data user to assist selection of the site location type that would be most representative for the required analysis. Table 4.1 lists the classification of each of the stations in the program.

Table 4.1 Ocean and river entrance tide site classification

Station	Classification	Classification code
Tweed Entrance South	Onshore River Entrance	OR
Tweed Offshore	Offshore Open Ocean	O
Brunswick Heads	Onshore River Entrance	OR
Ballina Breakwall	Onshore River Entrance	OR
Yamba	Onshore River Entrance	OR
Coffs Harbour	Onshore Bay or Port	OB
Port Macquarie	Onshore River Entrance	OR
Port Macquarie Offshore	Offshore Open Ocean	O
Crowdy Head	Onshore Bay or Port	OB
Forster	Onshore River Entrance	OR
Shoal Bay	Onshore Bay or Port	OB
Patonga	Onshore Bay or Port	OB

Station	Classification	Classification code
Sydney	Onshore Bay or Port	OB
Bundeena	Onshore Bay or Port	OB
Crookhaven Heads	Onshore River Entrance	OR
Shoalhaven Offshore	Offshore Open Ocean	O
Jervis Bay	Onshore Bay or Port	OB
Ulladulla	Onshore Bay or Port	OB
Princess Jetty	Onshore River Entrance	OR
Batemans Bay Offshore	Offshore Open Ocean	O
Bermagui	Onshore River Entrance	OR
Eden	Onshore Bay or Port	OB
Norfolk Island	Onshore Open Ocean	OO
Lord Howe Island	Onshore Open Ocean	OO

4.2 Program improvements/changes

Improvements and changes to the network have continued in 2019– 2020. Major changes are summarised below.

- On-site gauge statuses are now recorded on a digital form using an application which steps through safety procedures and relevant documentation before opening an easy-to-use data entry platform. All field statuses are now calculated automatically when taking a 15-minute point averaging status, only requiring known variables to be entered to give the actual water level height to compare with the logged readings. Data is then sent directly to the MHL database, removing the need to enter readings manually. This improvement increases the efficiency of on-site activities, along with enhancing safety culture.
- The Coffs Harbour logger box was moved to accommodate wharf renovations including a new electrical power conduit.
- All ocean tide and estuary stations have now been upgraded to high frequency 4G IP data transfers (with data available in near real-time, every 15 minutes). This improved communications network provides more reliable and faster data transfer between the logger and MHL's website after each point is logged.
- Three new loggers have been purchased to be installed at Lord Howe Island, Shoal Bay and Sydney. The new loggers will allow for faster communication between field computer and logger during station visits, as well as an inbuilt secure digital (SD) card reading system for improved reliability of 1-second data logging.

Table 4.2 shows the tidal logging and sensing system status of the sites as of June 2020.

Table 4.2 MHL tidal logging and sensing system status 1/7/2019–30/6/2020

Station	Latitude	Longitude	Site classif-ication[1]	Primary loggers[2]	Secondary loggers[2]	Primary sensors	Secondary sensors	Station	
								Sampling	Logging
Tweed Entrance South	-28.1706	153.5512	OR	4 Com	-	Radar	Vented pressure	120 samples averaged 1 minute either side of the quarter hour and 60 samples averaged 30 seconds either side of each minute and 9 sites logging at 1 second to onsite data storage card (Tweed Entrance South, Coffs Harbour, Port Macquarie, Lord Howe Island, Shoal Bay, Patonga, Sydney, Princess Jetty and Eden)	15 minutes on the quarter hour and 1 minute on the minute
Brunswick Heads	-28.5370	153.5528	OR	2 Com	-	Vented pressure	Vented pressure		
Ballina Breakwall	-28.8754	153.5844	OR	4 Com	-	Vented pressure	Vented pressure		
Yamba	-29.4290	153.3621	OR	2 Com	-	Radar	Vented pressure		
Coffs Harbour	-30.3029	153.1461	OB	4 Com	-	Radar	Vented pressure		
Port Macquarie	-31.4268	152.9111	OR	4 Com	-	Radar	Vented pressure		
Crowdy Head	-31.8387	152.7500	OB	2 Com	-	Radar	Vented pressure		
Forster	-32.1740	152.5082	OR	2 Com	-	Vented pressure	Vented pressure		
Shoal Bay	-32.7197	152.1757	OB	4 Com	-	Radar	Vented pressure		
Patonga	-33.5510	151.2746	OB	4 Com	-	Radar	Vented pressure		
Sydney	-33.8255	151.2585	OB	4 Com	-	Radar	n/a		
Sydney Backup	-33.8263	151.2572	OB	2 Com	-	Vented pressure	Vented pressure		
Bundeena	-34.0827	151.1509	OB	2 Com		Radar	n/a		
Crookhaven Heads	-34.9053	150.7594	OR	2 Com	-	Vented pressure	Vented pressure		
Jervis Bay	-35.1220	150.7074	OB	2 Com	-	Radar	Vented pressure		
Ulladulla	-35.3577	150.4765	OB	2 Com	-	Vented pressure	Vented pressure		
Princess Jetty	-35.7038	150.1778	OR	4 Com	-	Radar	Vented pressure		
Bermagui	-36.4263	150.0715	OR	2 Com	-	Vented pressure	Vented pressure		
Eden	-37.0712	149.9083	OB	4 Com	-	Radar	Vented pressure		
Lord Howe Island	-31.5236	159.0581	OO	4 Com	-	Radar	Vented pressure		
Tweed Offshore	-28.1811	153.5940	O	RBR Virtuoso	WLR7	Submersible Paroscientific Pressure Sensor and RBR Logger	Aanderaa submersible Pressure (only at 2 of the 4 sites per deployment year)	Integrated over 40 seconds	RBR 5 minutes Aanderaa 60 minutes
Port Macquarie Offshore	-31.4519	152.9455	O	RBR Virtuoso	WLR7				
Shoalhaven Offshore	-34.9165	150.7863	O	RBR Virtuoso	WLR7				
Batemans Bay Offshore	-35.7794	150.2533	O	RBR Virtuoso	WLR7				

[1] Classification: OR = Onshore River entrance, OB = Onshore Bay or Port, OO = Onshore Open Ocean, O = Offshore Open Ocean
[2] Loggers: 2 Com/4 Com = Indicating number of communication ports on the multi-channel programmable logger as per MHL Report 2546 (MHL 2020), RBR Virtuoso = RBR Ltd (Kanata, Canada), WLR7 = Aanderaa Data Instruments (Bergen, Norway)

4.3 Program plans 2020–2021

MHL is continuing to upgrade the ocean tide program to adopt best practice in data collection, maximise the efficiency of maintaining the program, increase data accuracy and capture, improve data resolution and increase the value of the data collected. The planned 2020–2021 program upgrades include:

- Predictions for all ocean tide stations to be calculated to 2025 based on the new epoch 2001–2020 with the Z_0 calculation from 2015–2020. The prediction method is referenced in the *Tidal methodologies report* (MHL Report 2156).
- Develop an on-line tide chart portal to complement the 2021 printed tide charts. This is proposed to enable users choice in predicted tide heights at various locations on the NSW coast. The portal would incorporate a flexible viewing date range along with a location option to add on the relevant time lag automatically.
- Undertake dive work to extend the Ballina Breakwall orifice to mitigate continuing siltation and infrastructure erosion problems experienced by the gauge, which is affecting the water level sensor performance.
- Upgrade the existing Ulladulla Boat Harbour double pressure transducer to a radar unit (delayed in 2019–2020 due to COVID-19 risk management requirements) to improve the reliability of the gauge.
- Finalise the offshore tide metadata report using updated photos obtained from the 2019–2020 offshore instrument extractions. The report will facilitate divers to better identify instrument locations and site conditions.

5. References

Foreman, MGG 1977, *Manual for tidal heights analysis and prediction*, Pac. Mar. Sci. Rep. 77-10, Inst. of Ocean Sciences, Patricia Bay, Sidney, B.C., 58pp (2004 revision).

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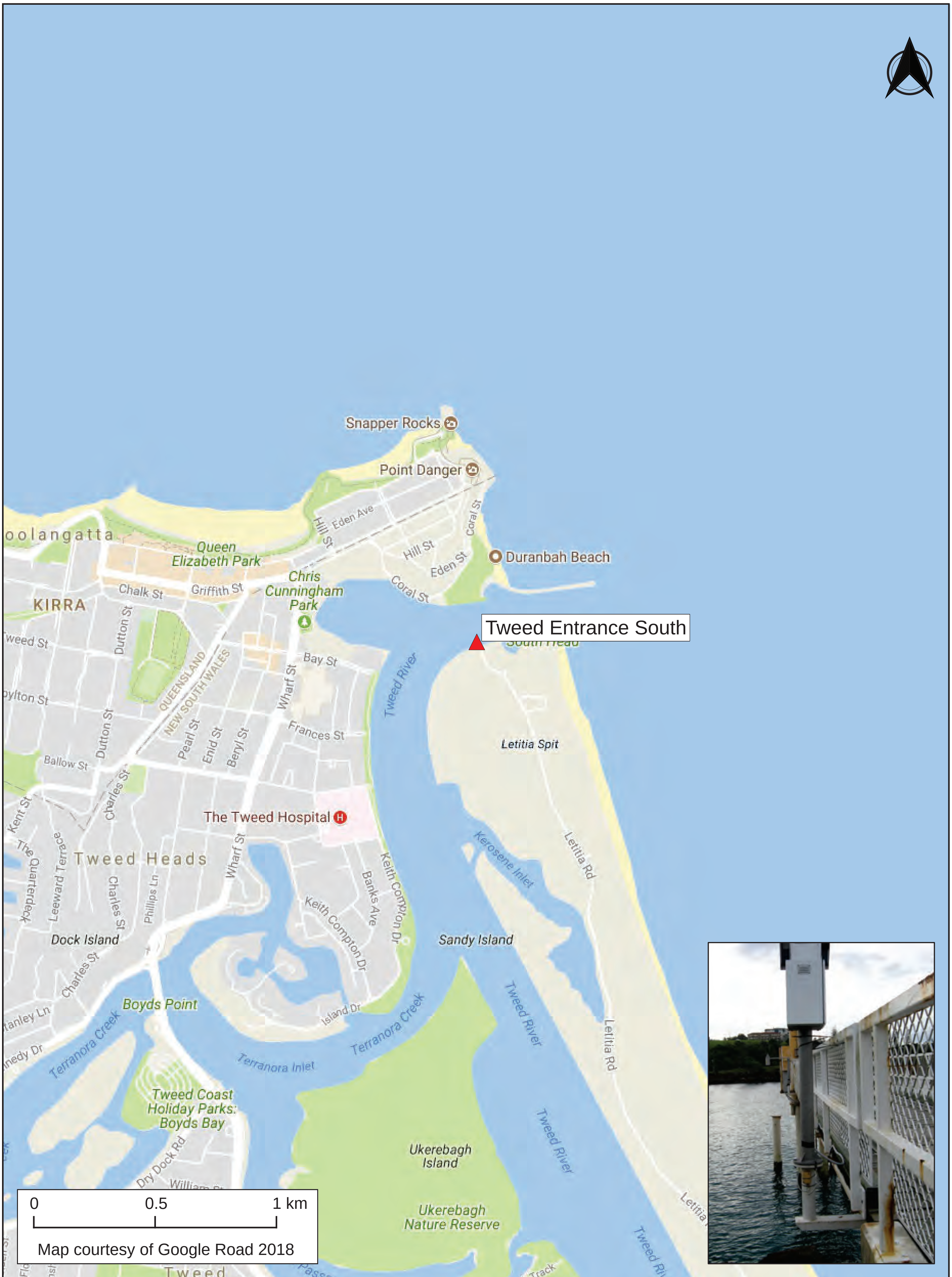
MHL 2012, *OEH NSW Tidal Planes Analysis 1990 – 2010 Harmonic Analysis*, MHL Report 2053, October 2012.

MHL 2017, *NSW Ocean and River Entrance Tidal Levels Annual Summary*, MHL Report 2574, December 2017.

MHL 2018, *NSW Extreme Ocean Water Levels*, MHL Report 2236, December 2018.

MHL 2019, *Review of NSW OEH Automatic Water Level Recorder Network,* MHL Report 2546, March 2019.

Appendix A Annual data site summaries



TWEED ENTRANCE SOUTH
STATION LOCATION

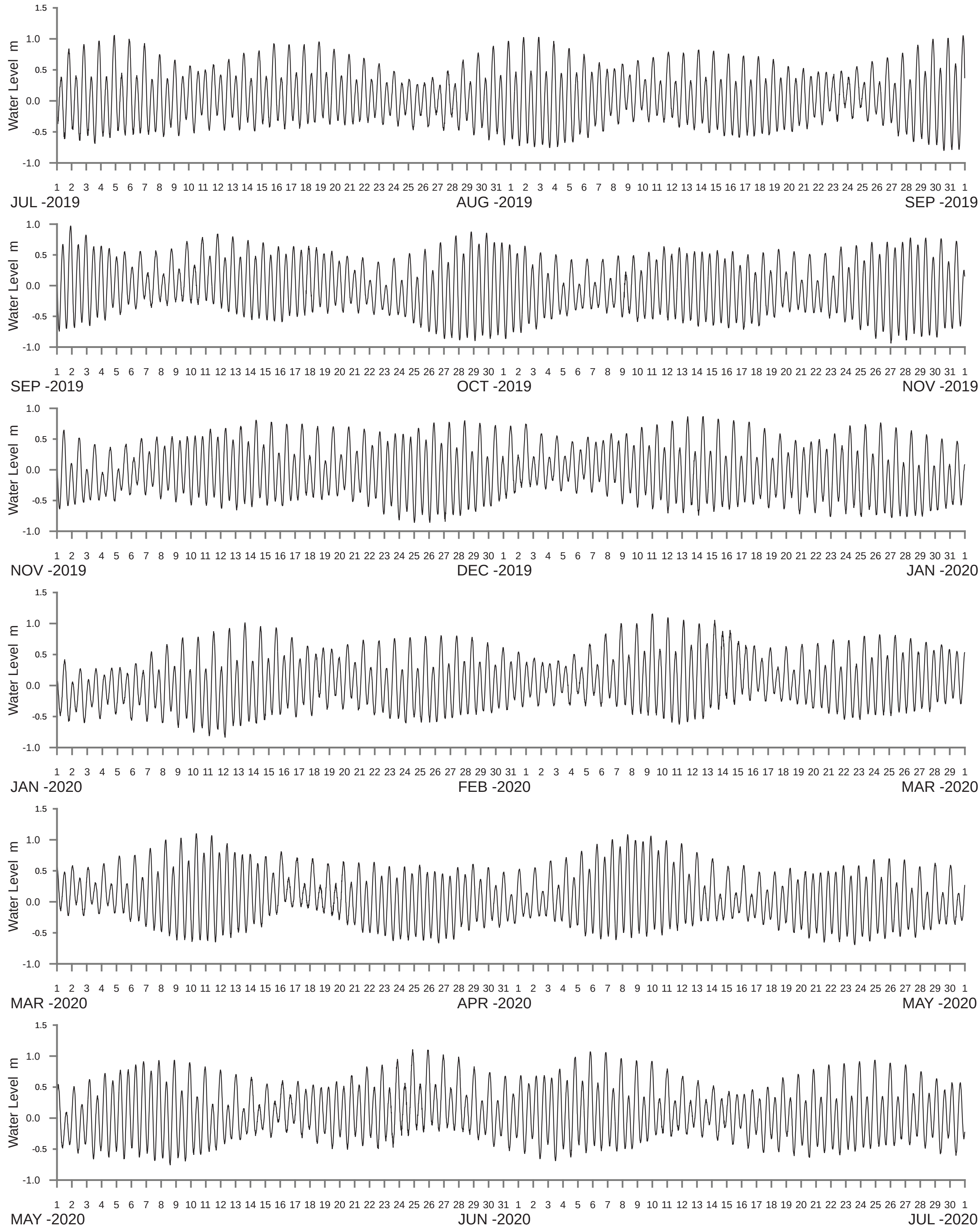
Manly Hydraulics Laboratory

Report MHL2770

Figure

A1

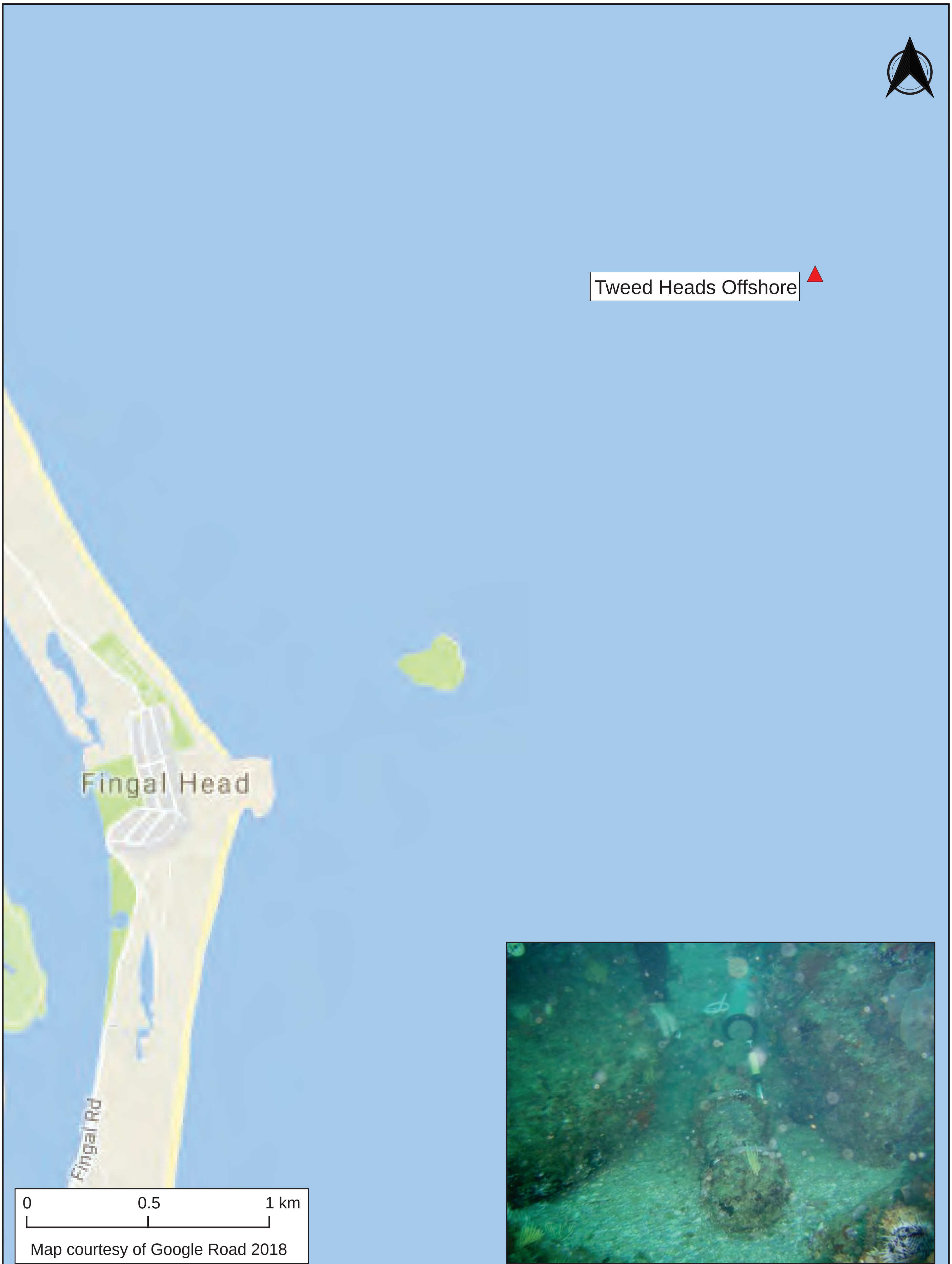
DRAWING 2770-A1.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT	TWEED ENTRANCE SOUTH DATA SUMMARY 2019–2020	Manly Hydraulics Laboratory Report MHL2770 Figure A2 DRAWING 2770-A2.cdr



NSW GOVERNMENT

TWEED HEADS OFFSHORE
STATION LOCATION

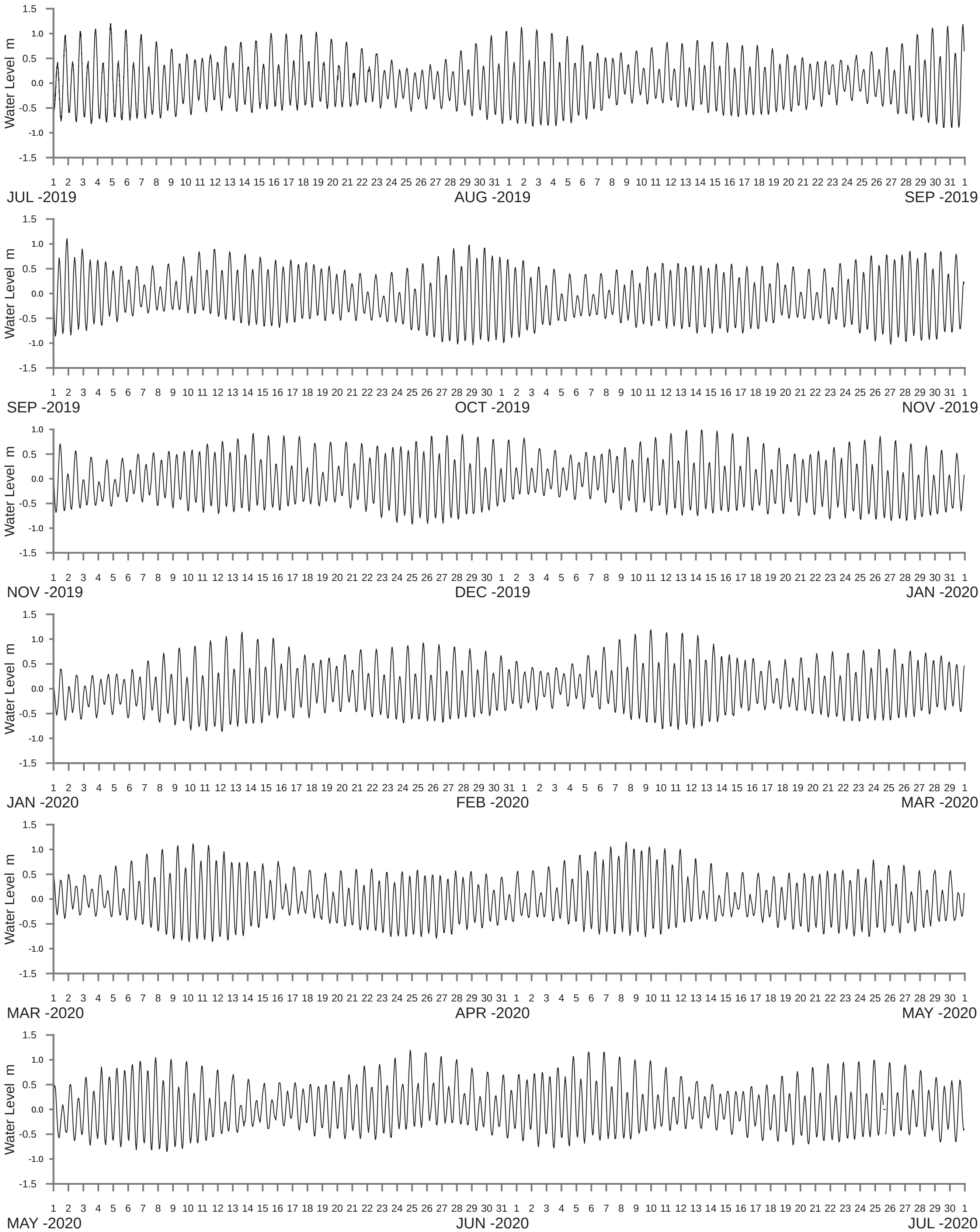
Manly Hydraulics Laboratory

Report MHL2770

Figure

A3

DRAWING 2770-A3.cdr



WATER LEVEL REFERENCED TO MEAN SEA LEVEL

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

NSW GOVERNMENT

TWEED HEADS OFFSHORE DATA SUMMARY
2019–2020

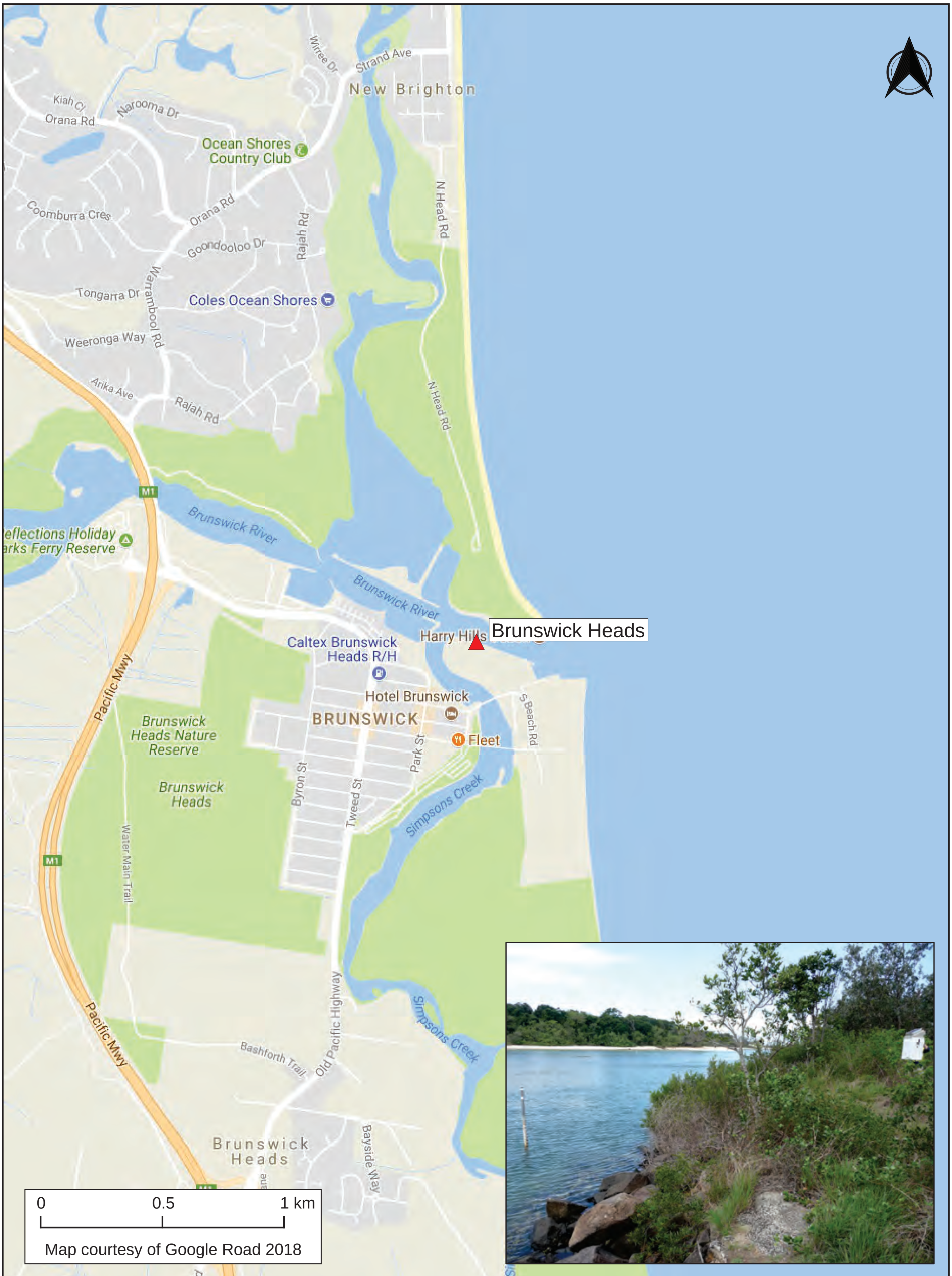
Manly Hydraulics Laboratory

Report MHL2770

Figure

A4

DRAWING 2770-A4.cdr



NSW GOVERNMENT

BRUNSWICK HEADS
STATION LOCATION

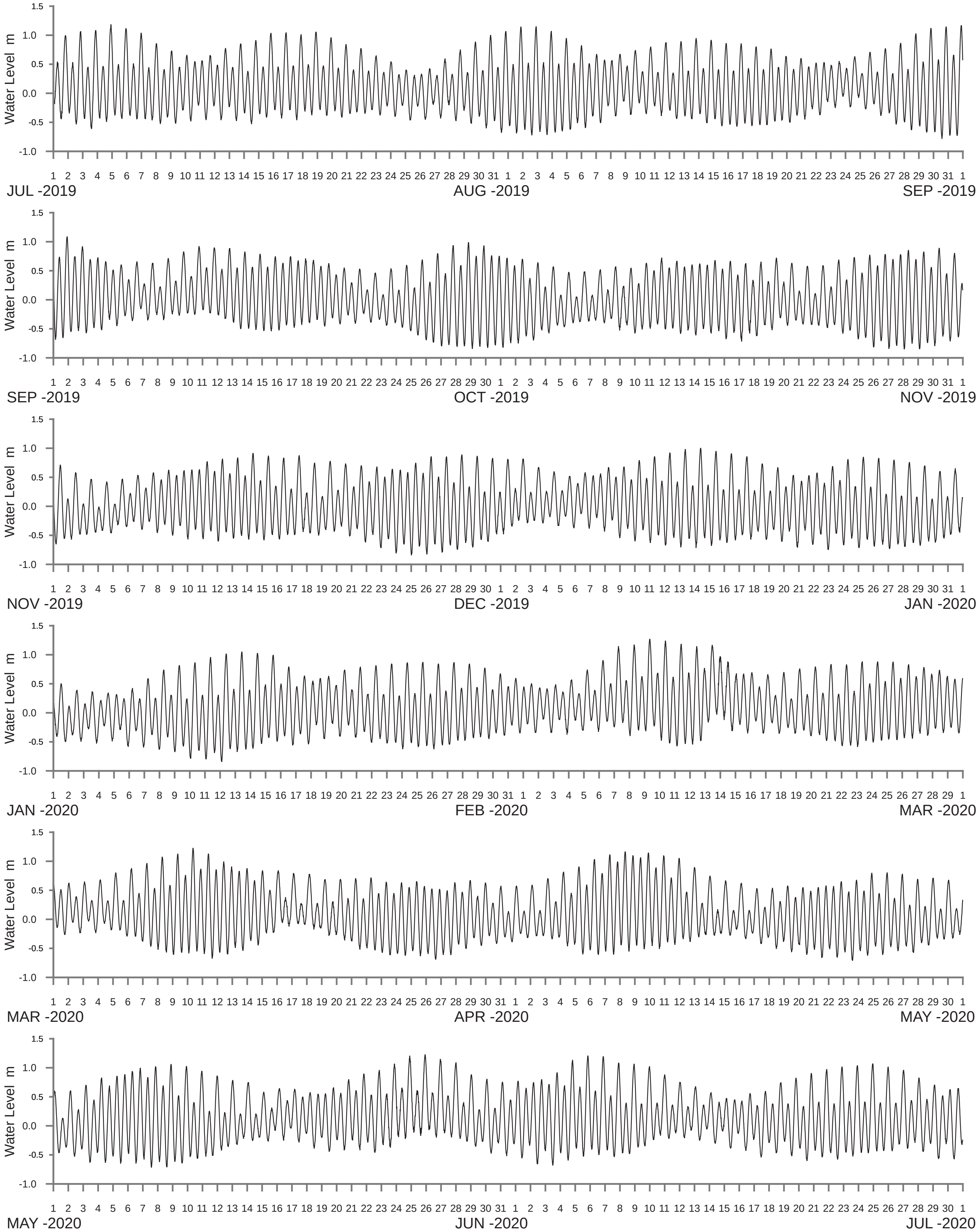
Manly Hydraulics Laboratory

Report MHL2770

Figure

A5

DRAWING 2770-A5.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT

BRUNSWICK HEADS DATA SUMMARY
2019–2020

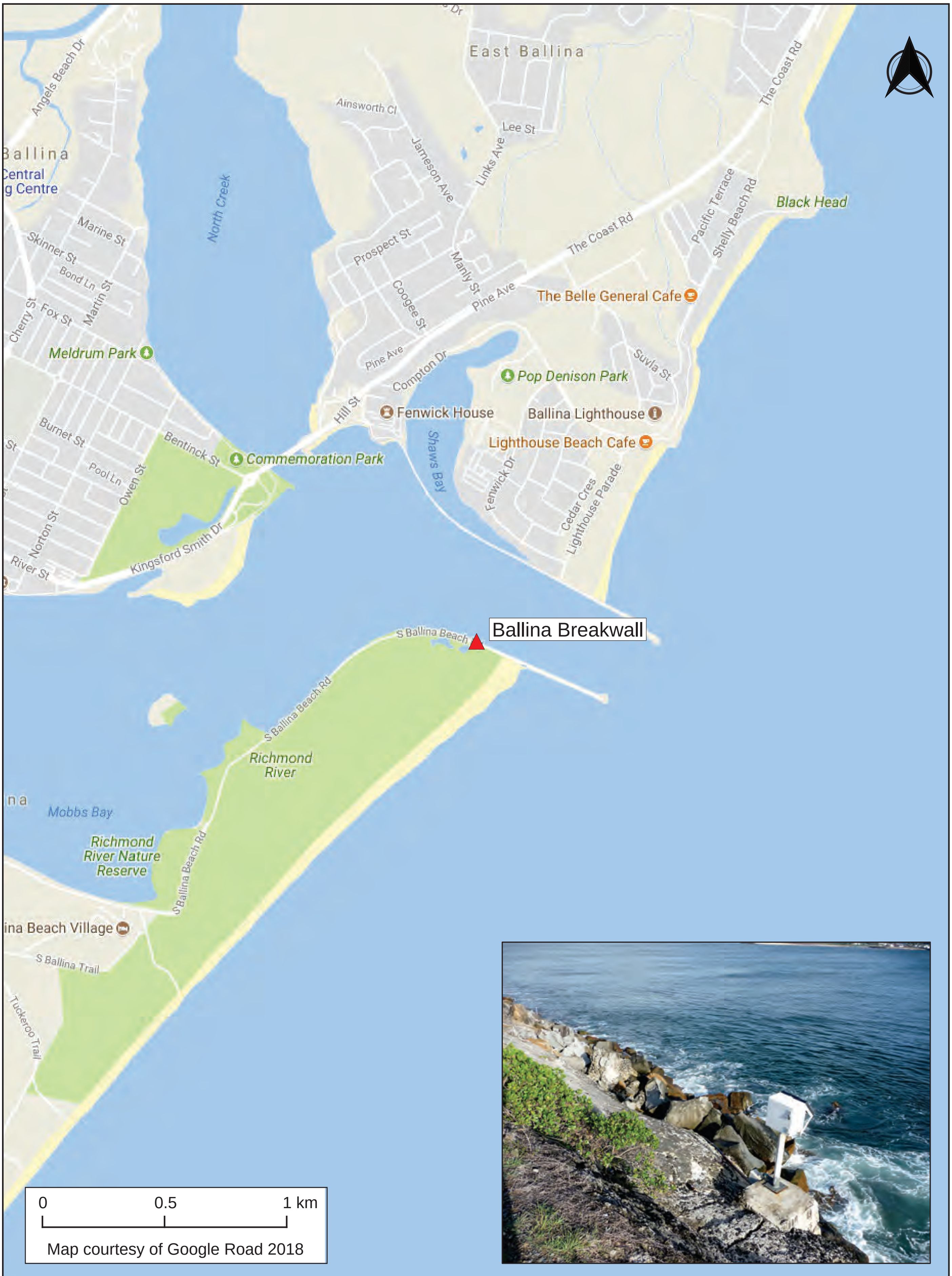
Manly Hydraulics Laboratory

Report MHL2770

Figure

A6

DRAWING 2770-A6.cdr



NSW GOVERNMENT

BALLINA BREAKWALL
STATION LOCATION

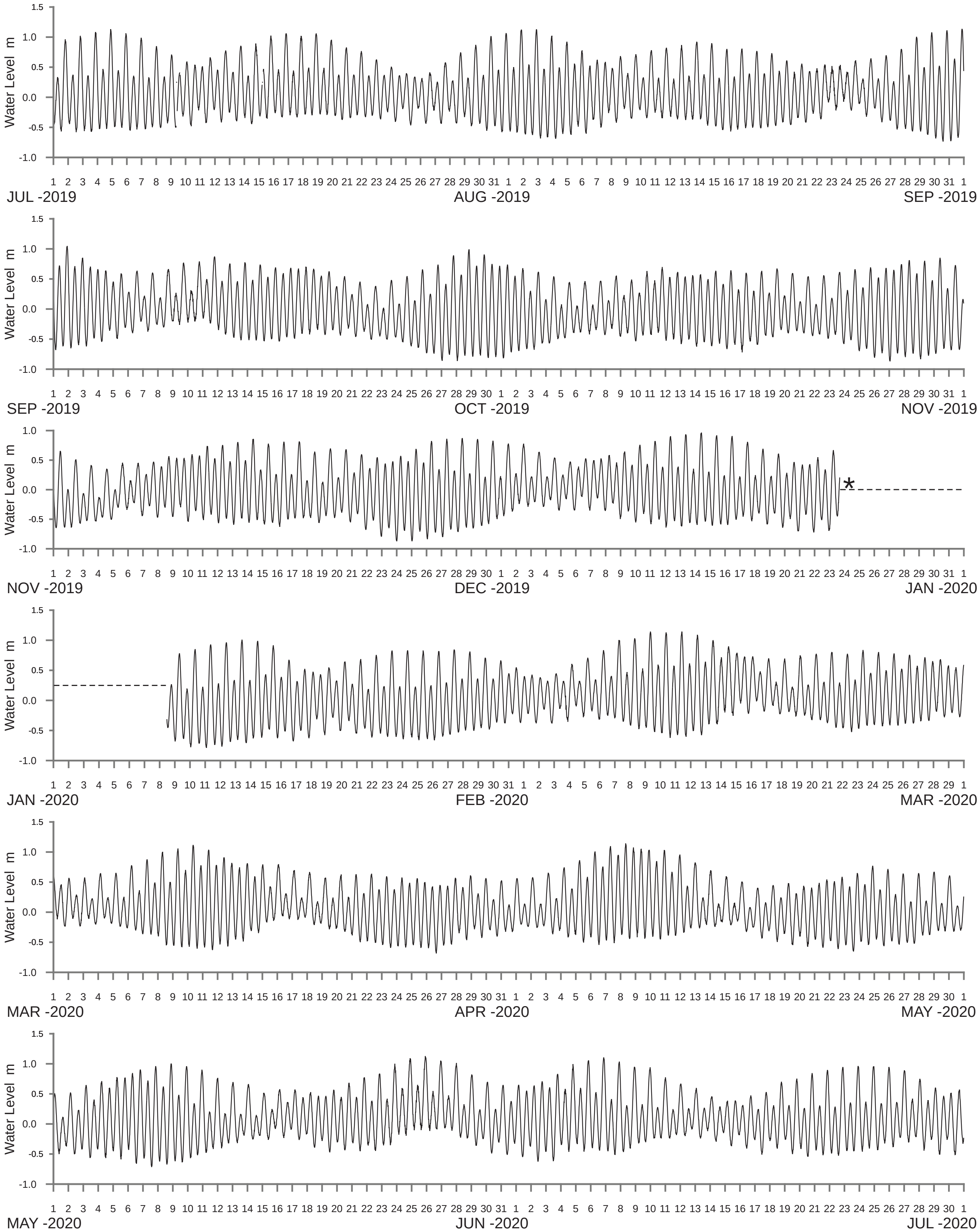
Manly Hydraulics Laboratory

Report MHL2770

Figure

A7

DRAWING 2770-A7.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

*Orifice loosened after bracket corrosion.

NSW GOVERNMENT

BALLINA BREAKWALL DATA SUMMARY
2019–2020

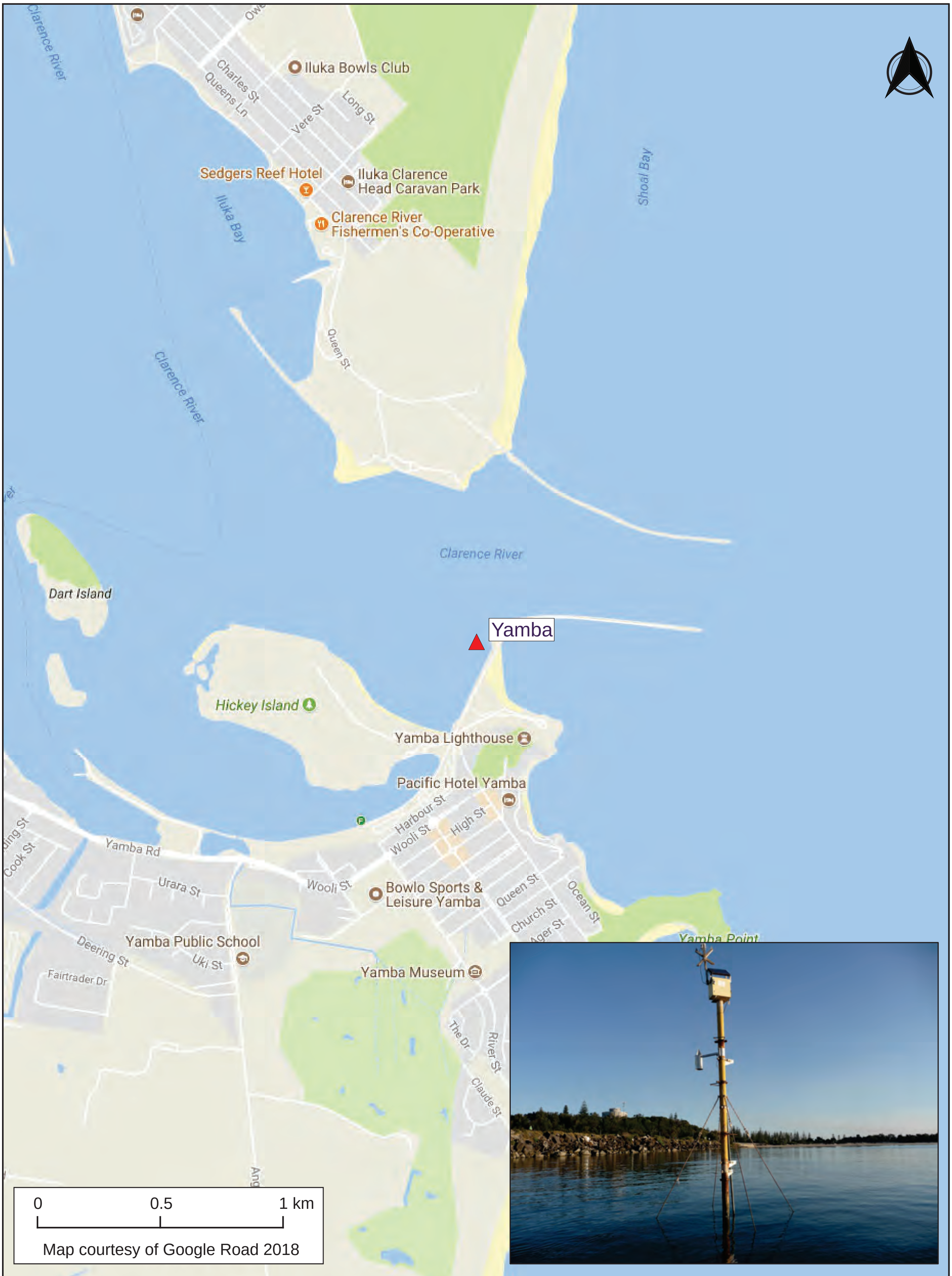
Manly Hydraulics Laboratory

Report MHL2770

Figure

A8

DRAWING 2770-A8.cdr



YAMBA
STATION LOCATION

Manly Hydraulics Laboratory

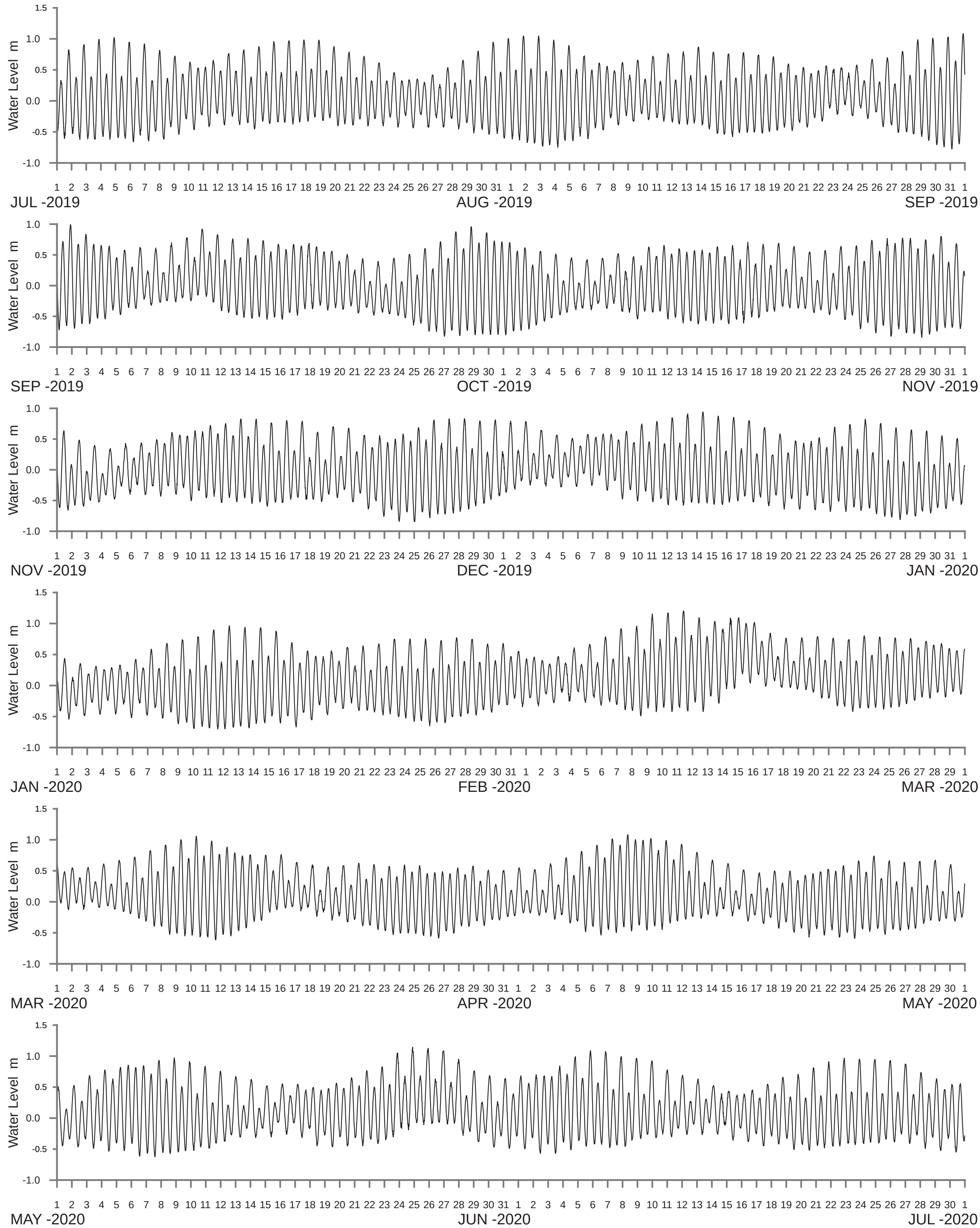
Report MHL2770

Figure

A9

DRAWING 2770-A9.cdr

NSW GOVERNMENT



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT

YAMBA DATA SUMMARY
2019–2020

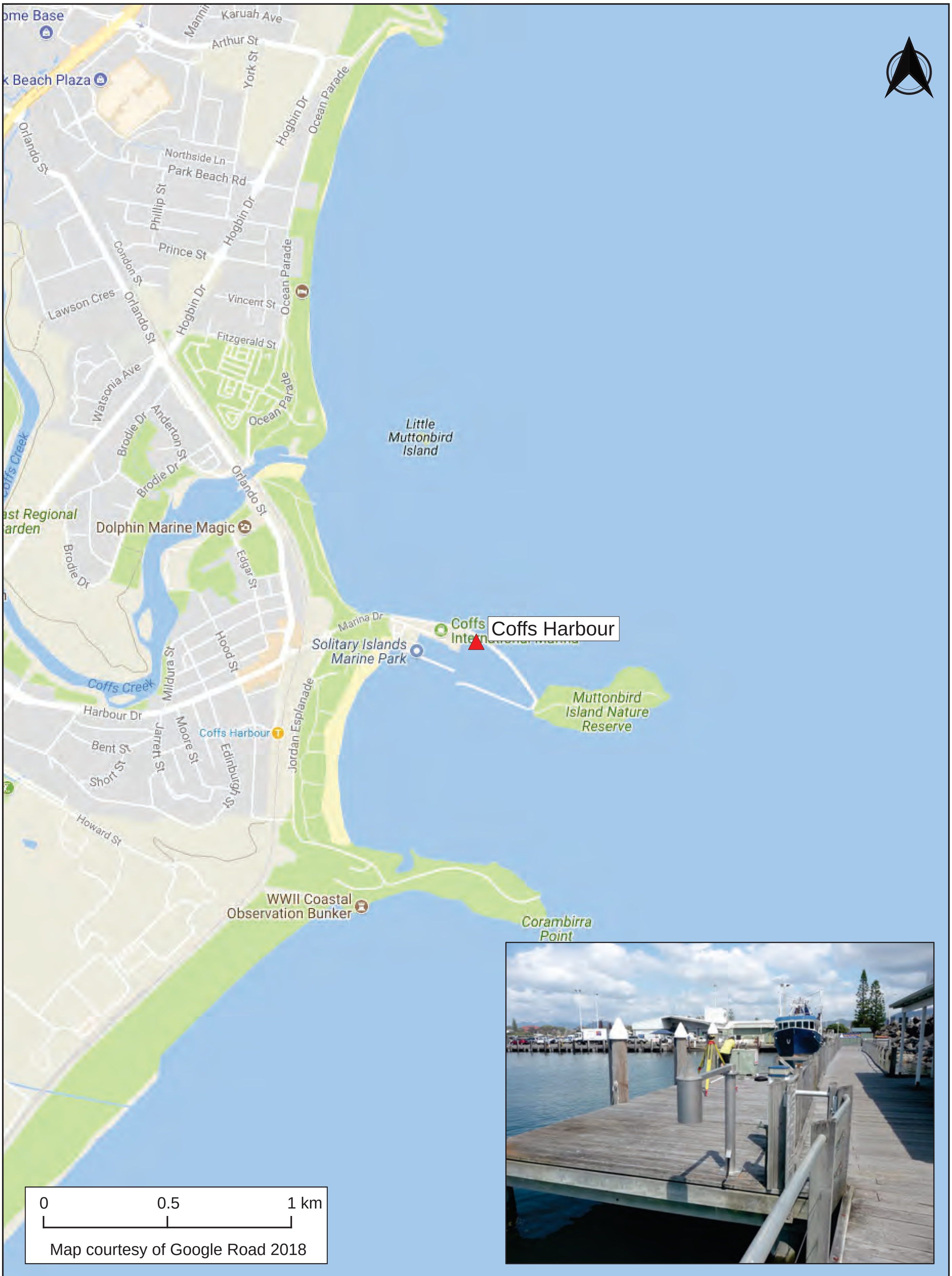
Manly Hydraulics Laboratory

Report MHL2770

Figure

A10

DRAWING 2770-A10.cdr



COFFS HARBOUR
STATION LOCATION

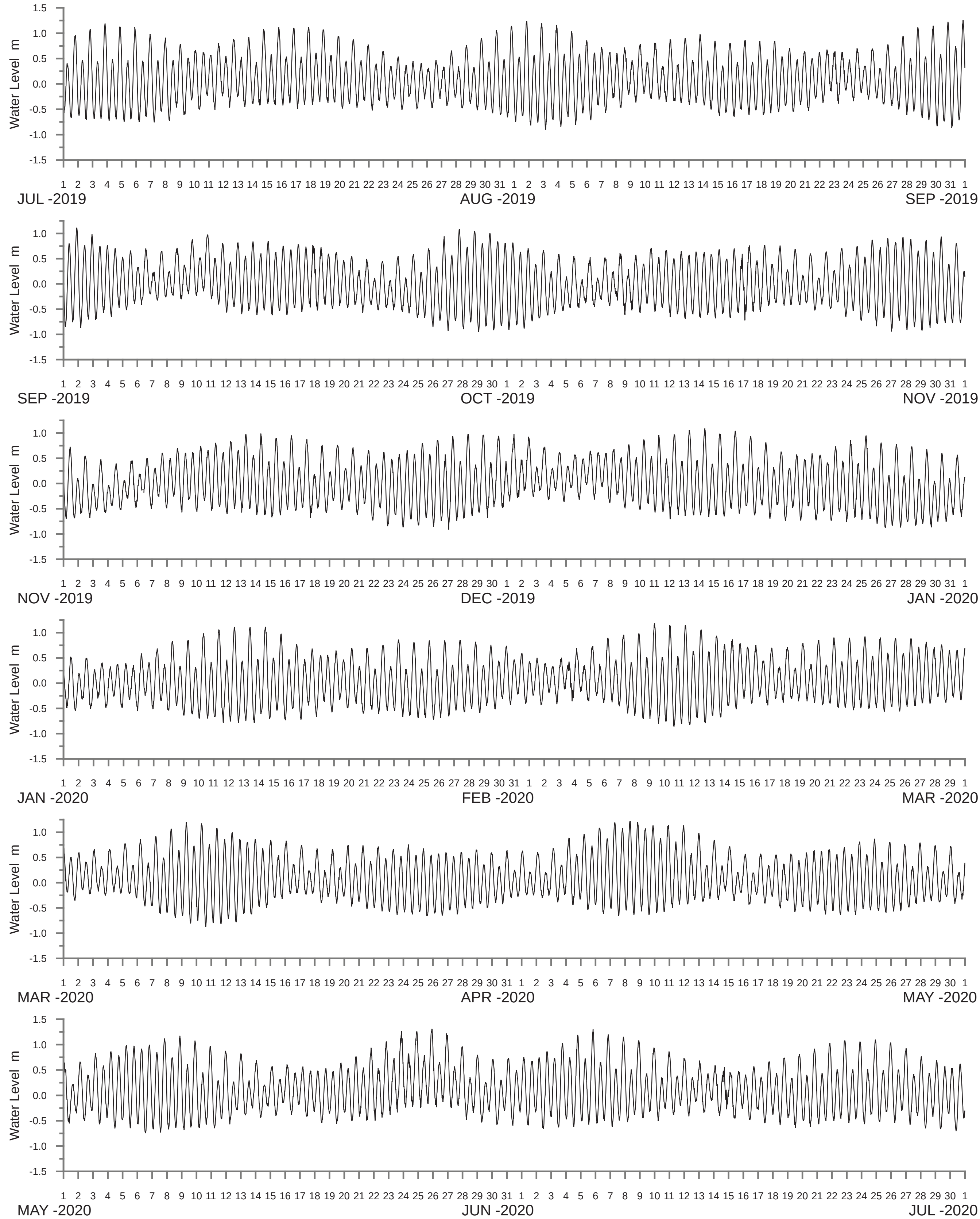
Manly Hydraulics Laboratory

Report MHL2770

Figure

A11

DRAWING 2770-A11.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT

COFFS HARBOUR DATA SUMMARY
2019–2020

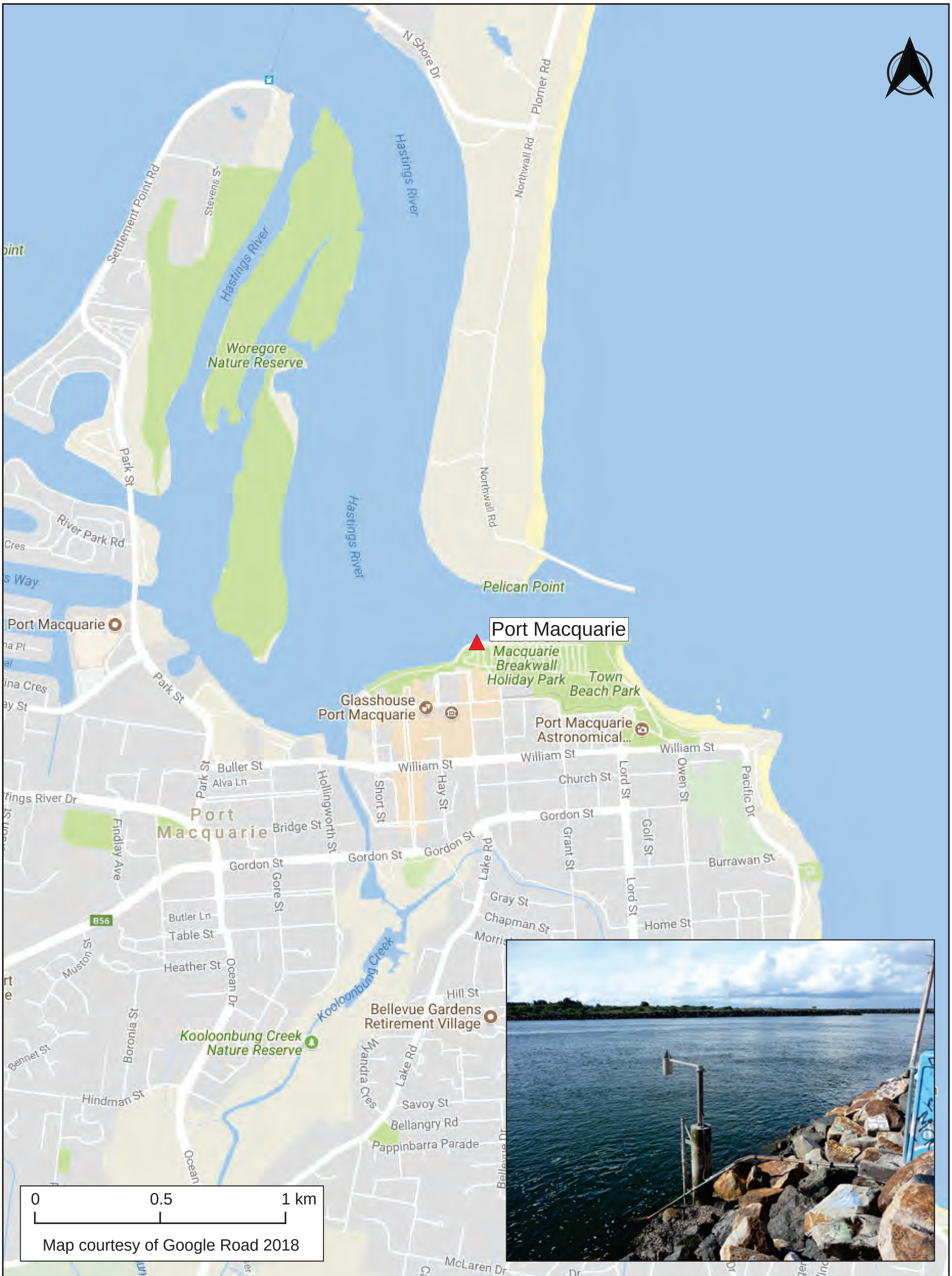
Manly Hydraulics Laboratory

Report MHL2770

Figure

A12

DRAWING 2770-A12.cdr



NSW GOVERNMENT

PORT MACQUARIE
STATION LOCATION

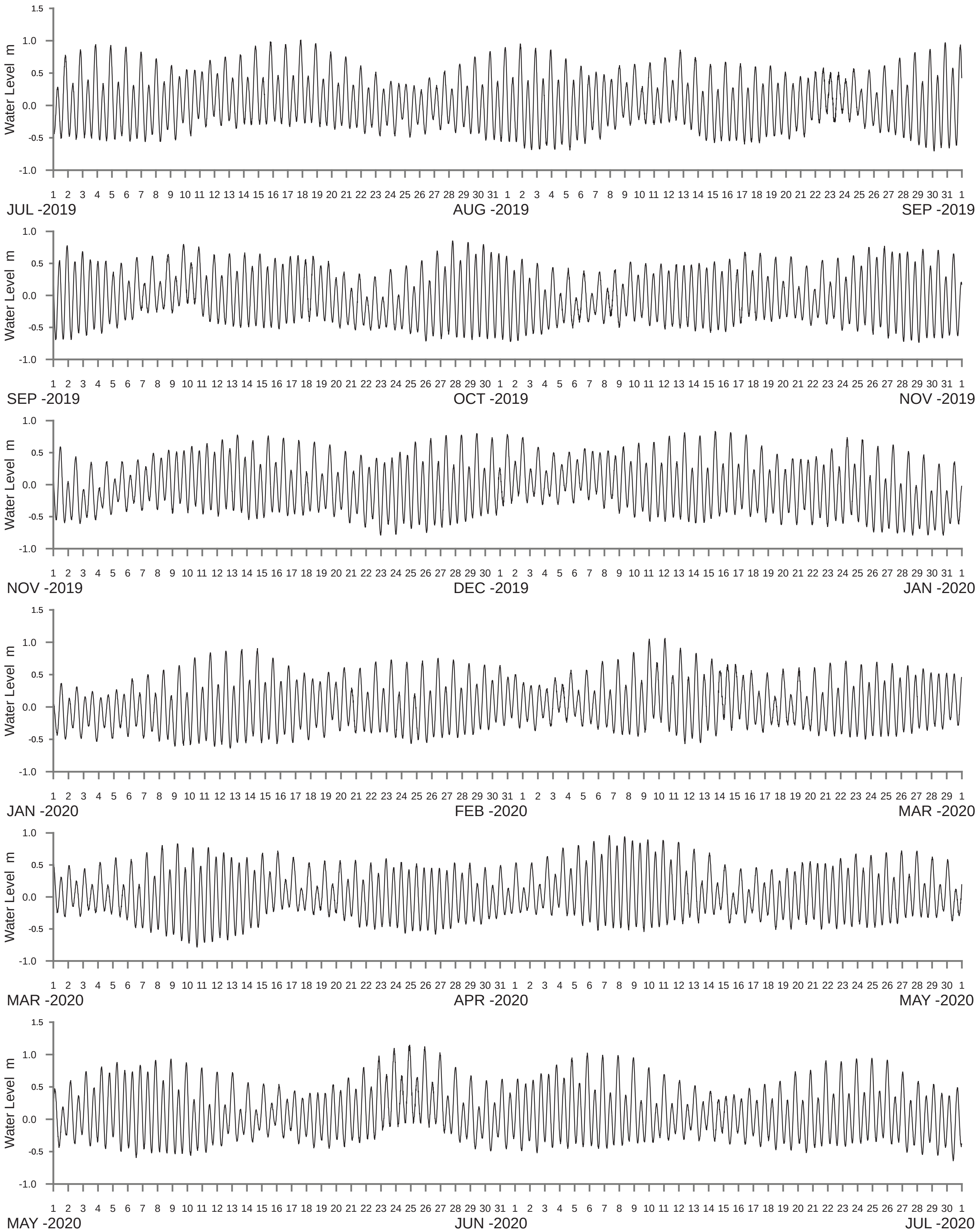
Manly Hydraulics Laboratory

Report MHL2770

Figure

A13

DRAWING 2770-A13.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

PORT MACQUARIE DATA SUMMARY
2019–2020

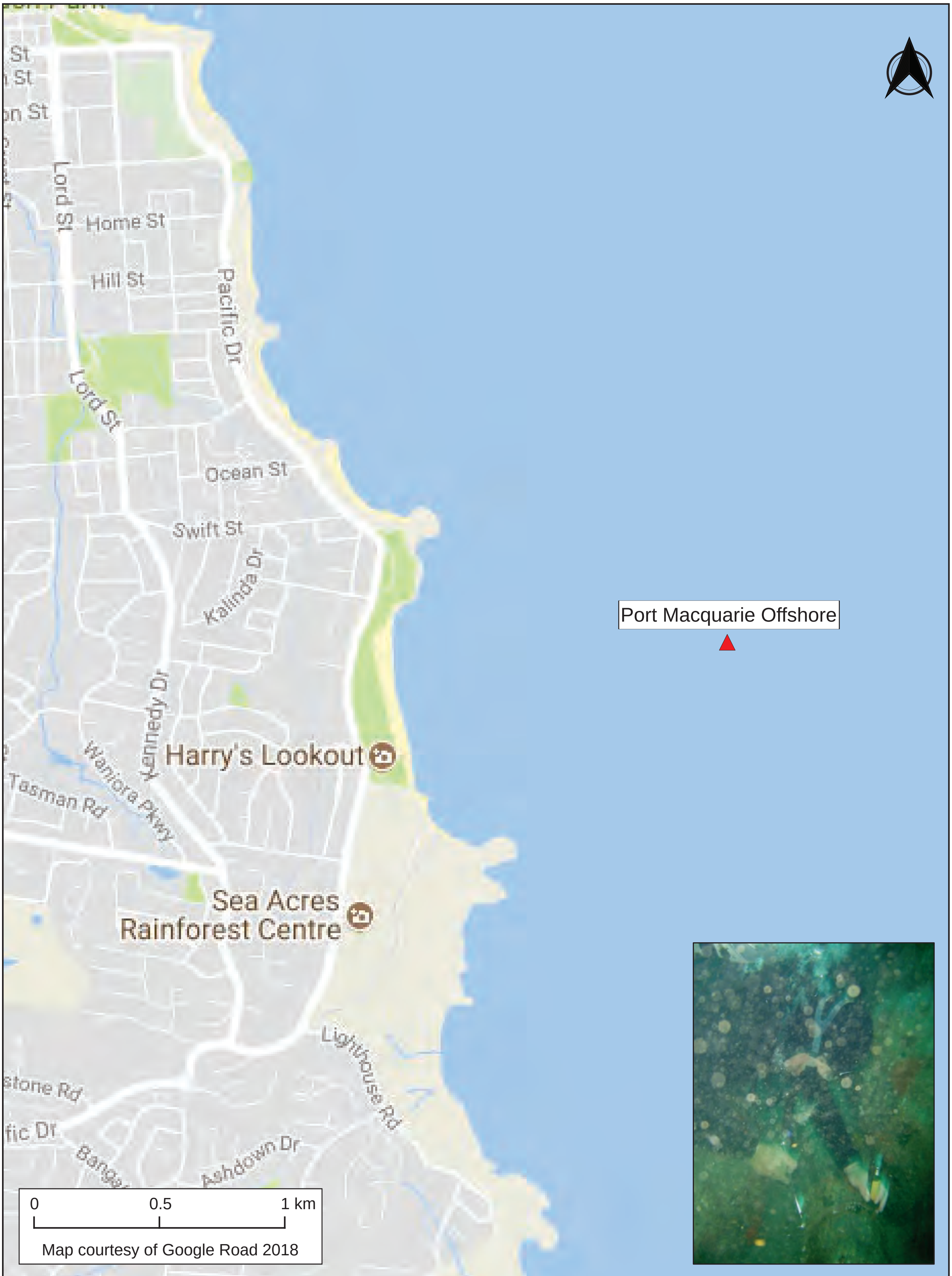
Manly Hydraulics Laboratory

Report MHL2770

Figure

A14

DRAWING 2770-A14.cdr



NSW GOVERNMENT

PORT MACQUARIE OFFSHORE
STATION LOCATION

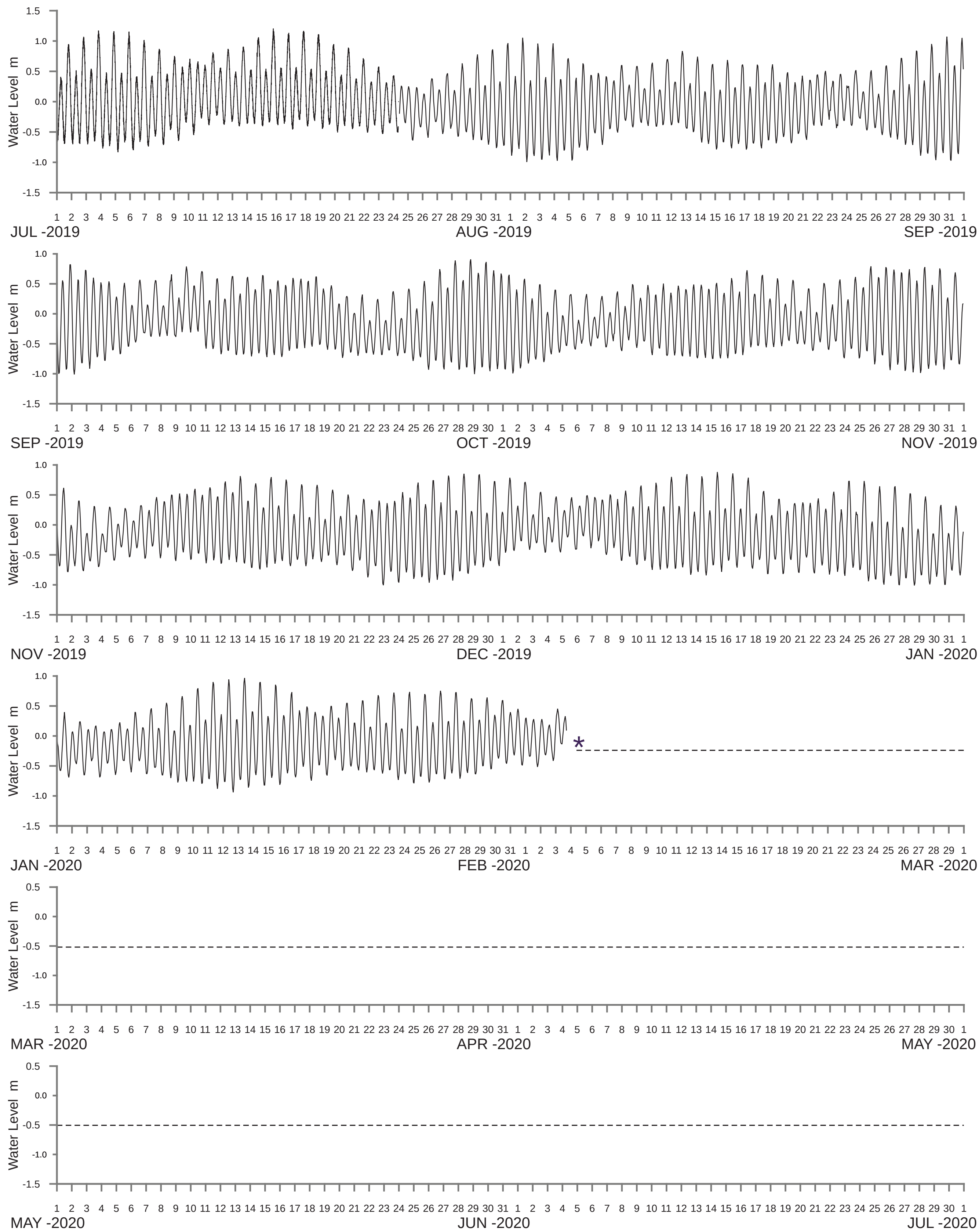
Manly Hydraulics Laboratory

Report MHL2770

Figure

A15

DRAWING 2770-A15.cdr



WATER LEVEL REFERENCED TO MEAN SEA LEVEL

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

*Logger lost to water ingress, backup had marine growth buildup after a certain period of time.

NSW GOVERNMENT

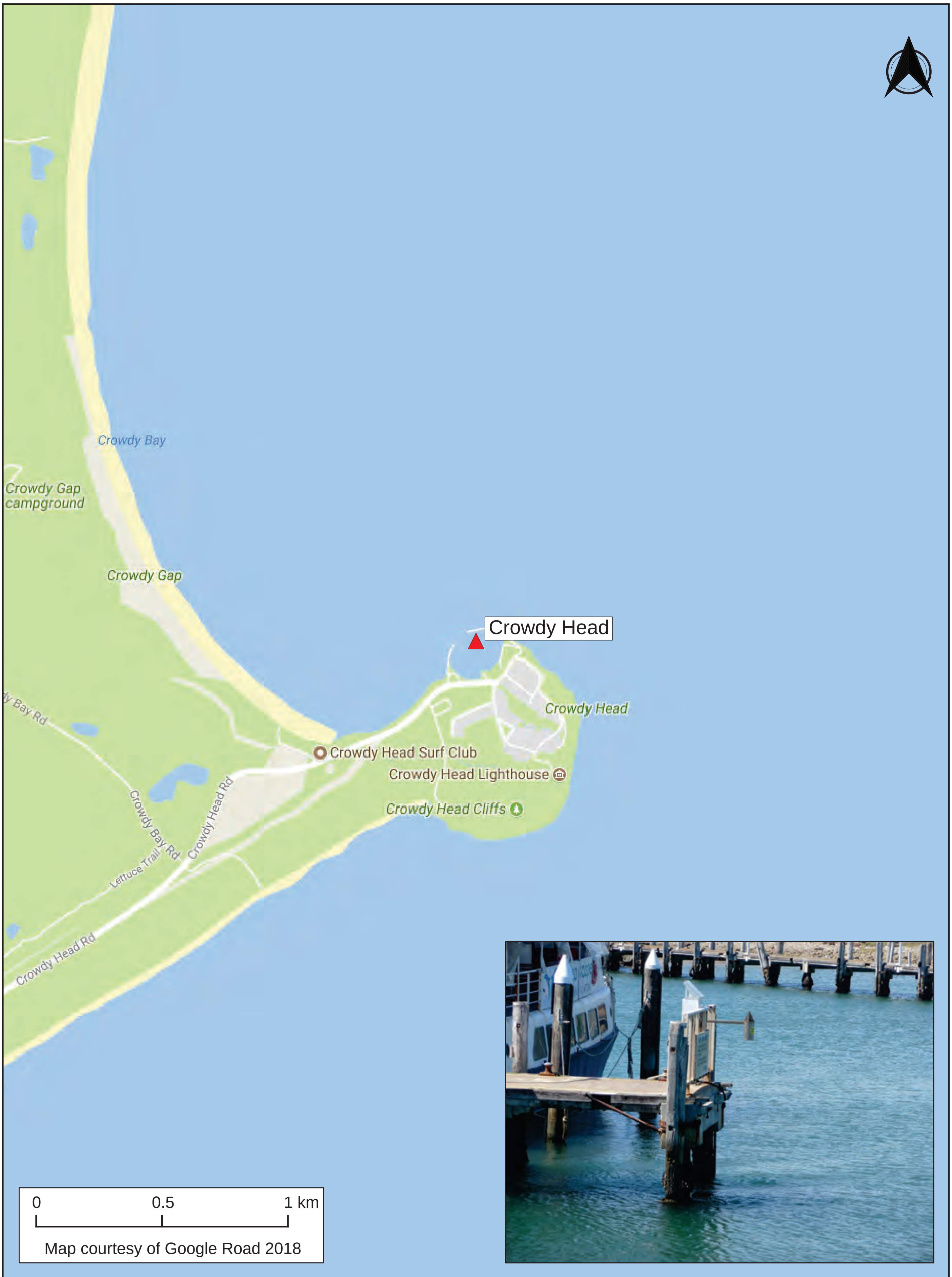
PORT MACQUARIE OFFSHORE DATA SUMMARY
2019–2020

Manly Hydraulics Laboratory

Report MHL2770

Figure
A16

DRAWING 2770-A16.cdr



NSW GOVERNMENT

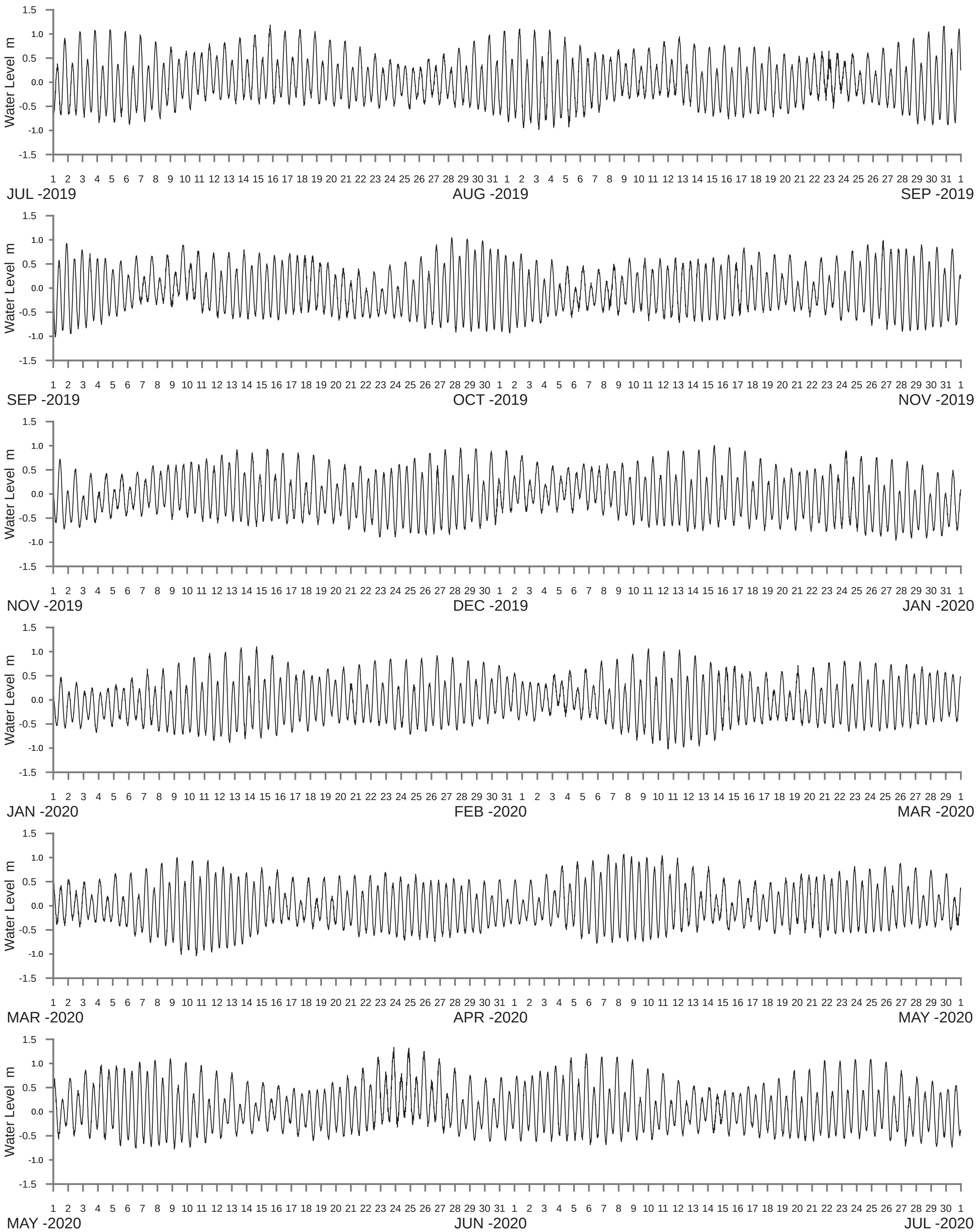
CROWDY HEAD
STATION LOCATION

Manly Hydraulics Laboratory

Report MHL2770

Figure A17

DRAWING 2770-A17.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT

CROWDY HEAD DATA SUMMARY
2019–2020

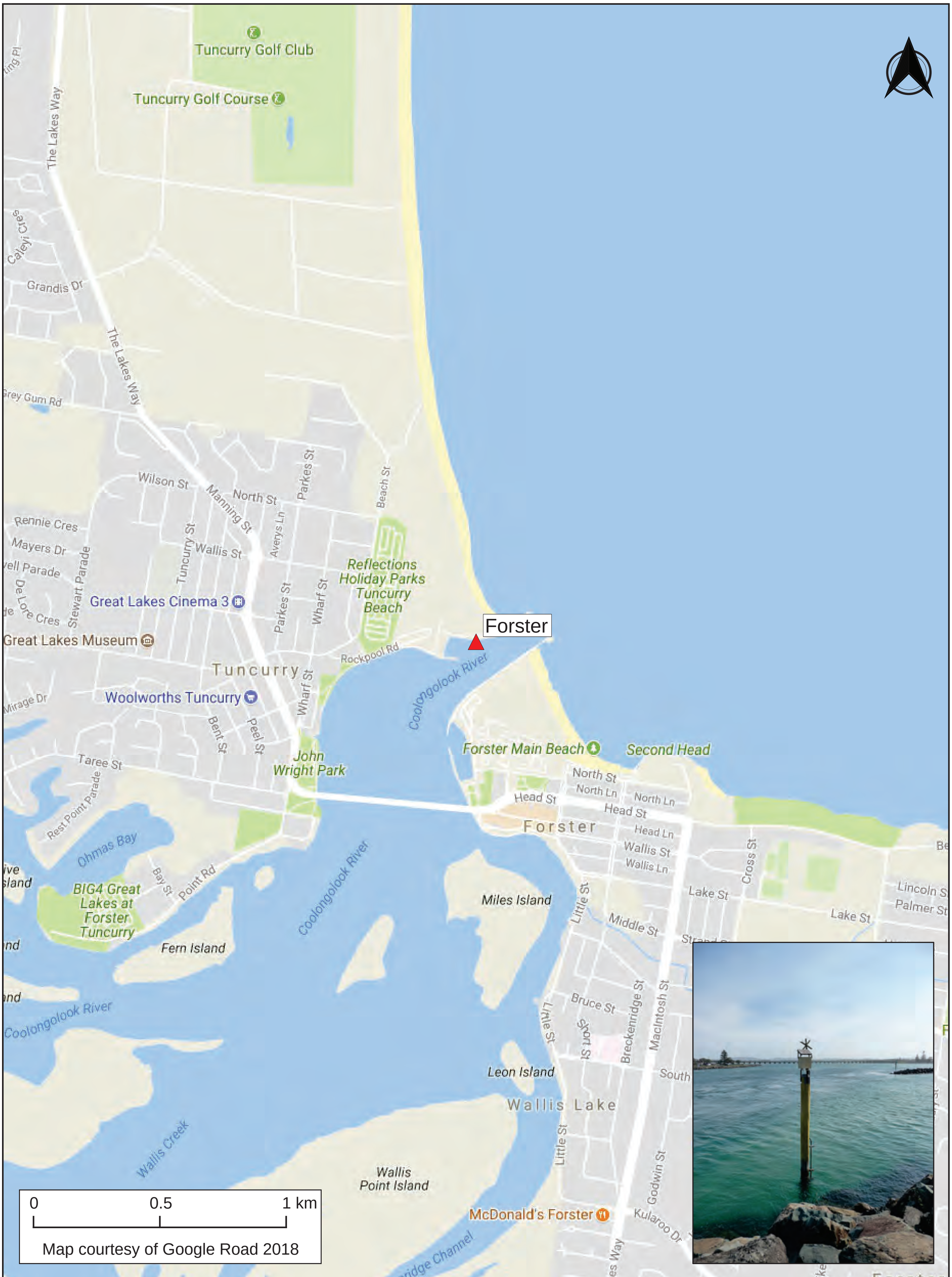
Manly Hydraulics Laboratory

Report MHL2770

Figure

A18

DRAWING 2770-A18.cdr



NSW GOVERNMENT

FORSTER
STATION LOCATION

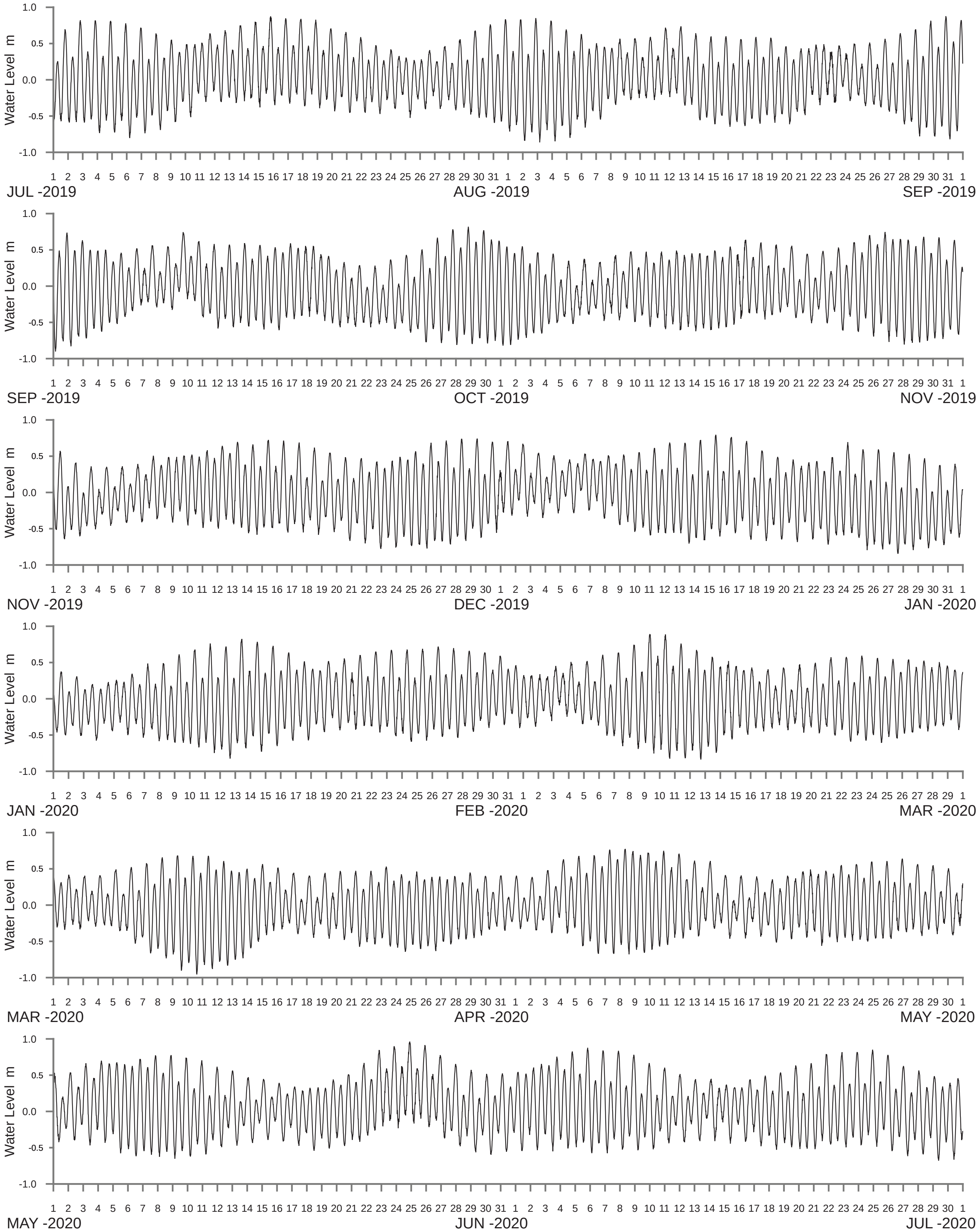
Manly Hydraulics Laboratory

Report MHL2770

Figure

A19

DRAWING 2770-A19.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT

FORSTER DATA SUMMARY
2019–2020

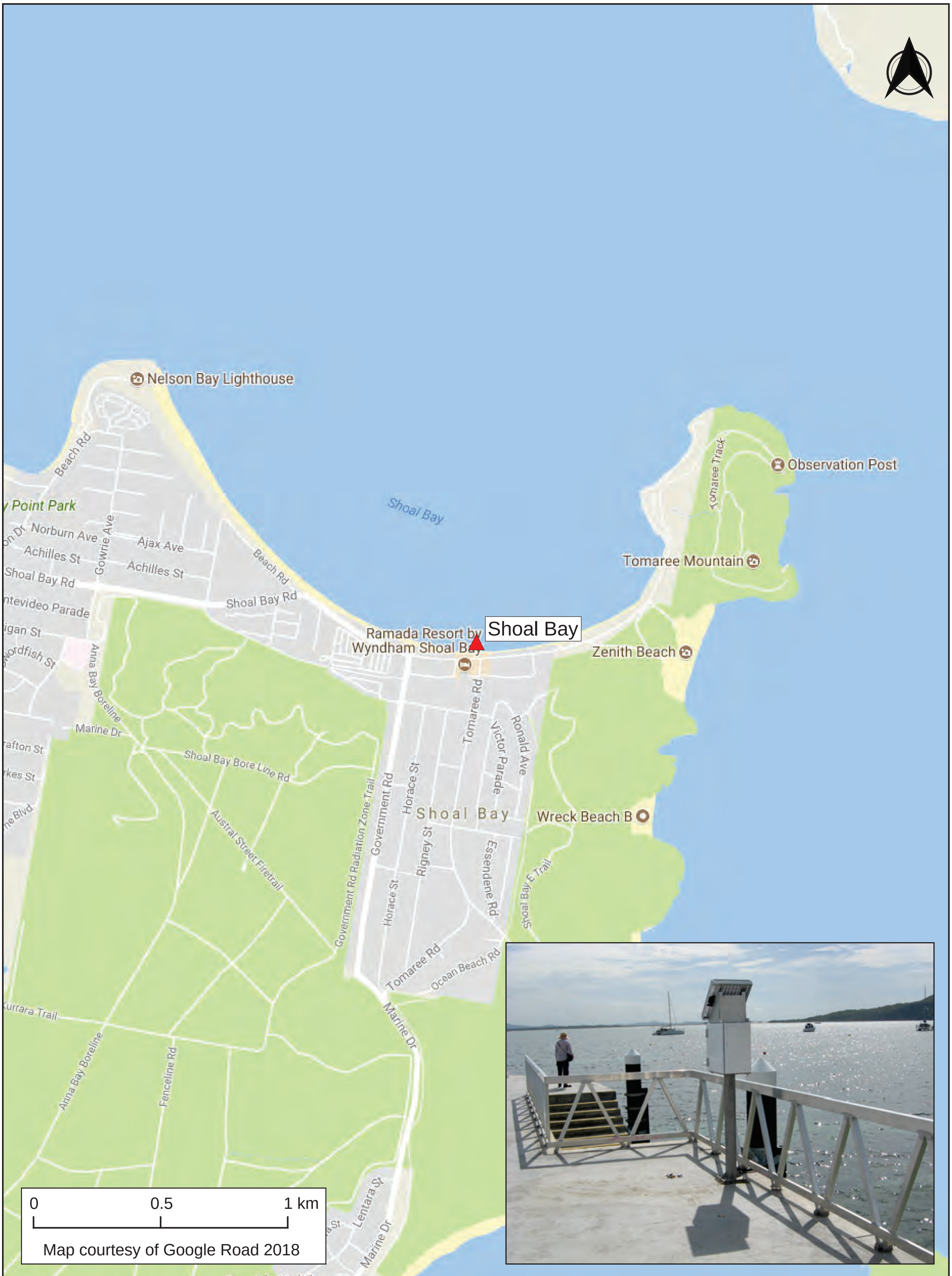
Manly Hydraulics Laboratory

Report MHL2770

Figure

A20

DRAWING 2770-A20.cdr



NSW GOVERNMENT

SHOAL BAY
STATION LOCATION

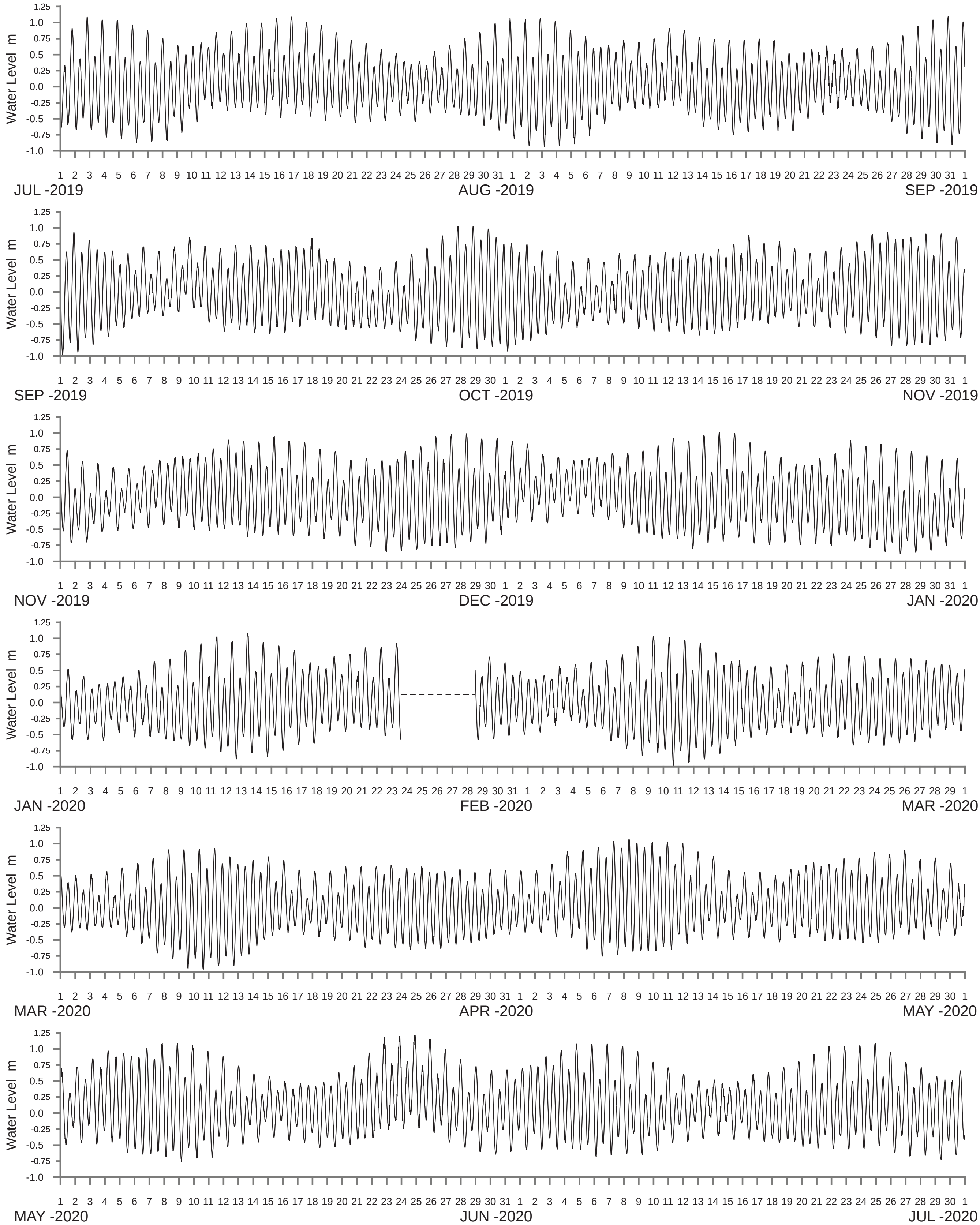
Manly Hydraulics Laboratory

Report MHL2770

Figure

A21

DRAWING 2770-A21.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT

SHOAL BAY DATA SUMMARY
2019–2020

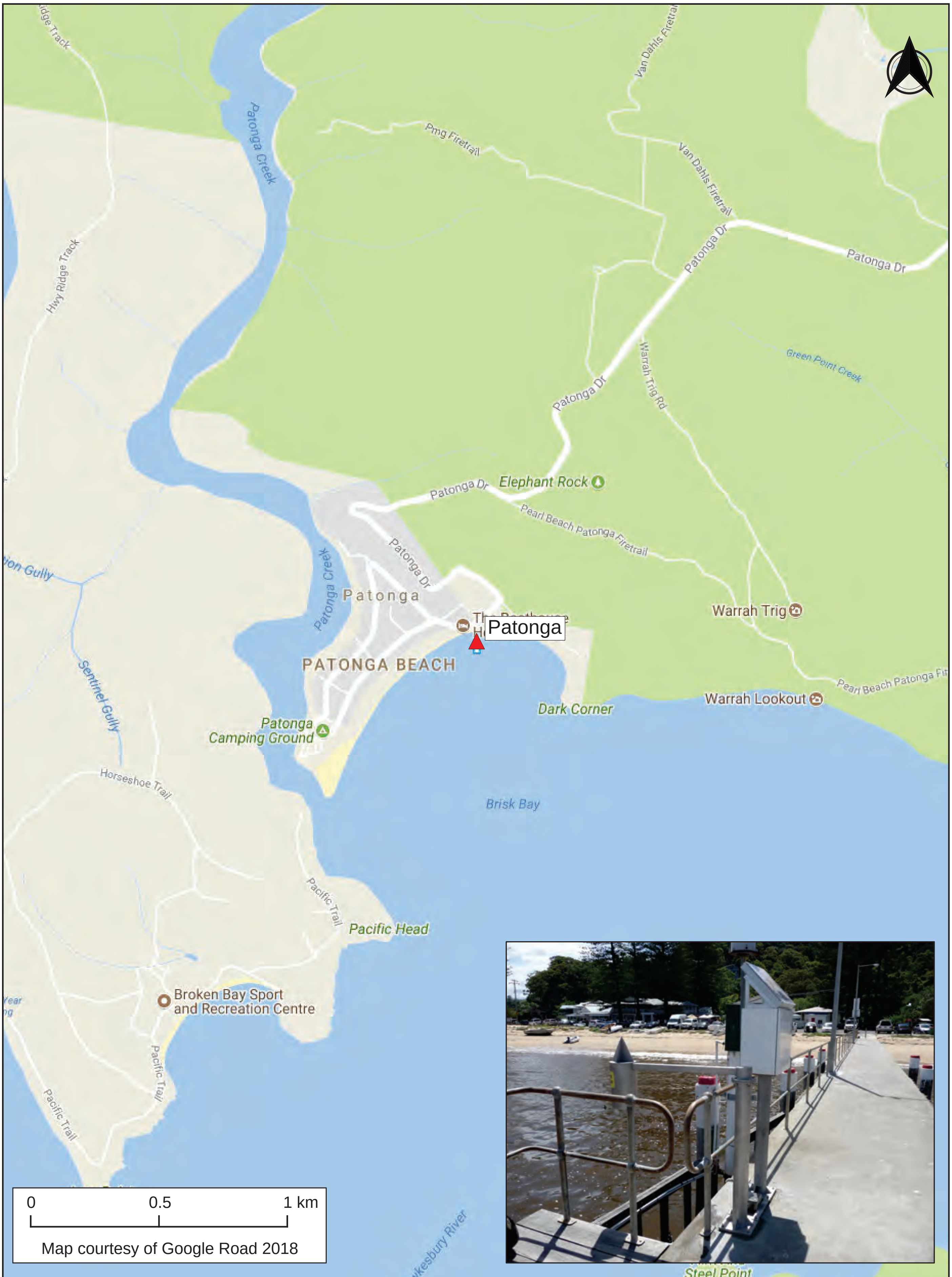
Manly Hydraulics Laboratory

Report MHL2770

Figure

A22

DRAWING 2770-A22.cdr



PATONGA
STATION LOCATION

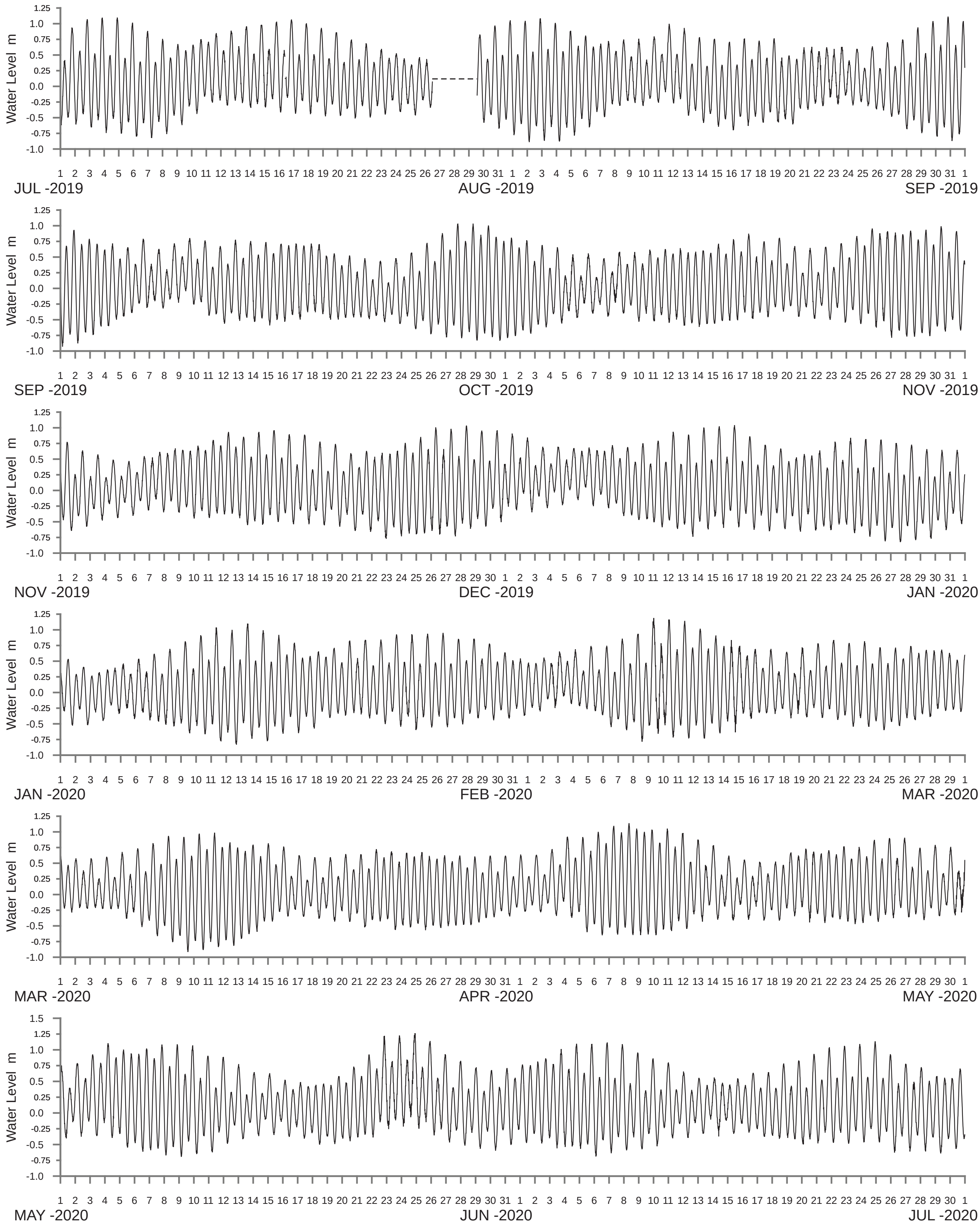
Manly Hydraulics Laboratory

Report MHL2770

Figure

A23

DRAWING 2770-A23.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT

PATONGA DATA SUMMARY
2019–2020

Manly Hydraulics Laboratory

Report MHL2770

Figure

A24

DRAWING 2770-A24.cdr

NSW GOVERNMENT

SYDNEY
STATION LOCATION

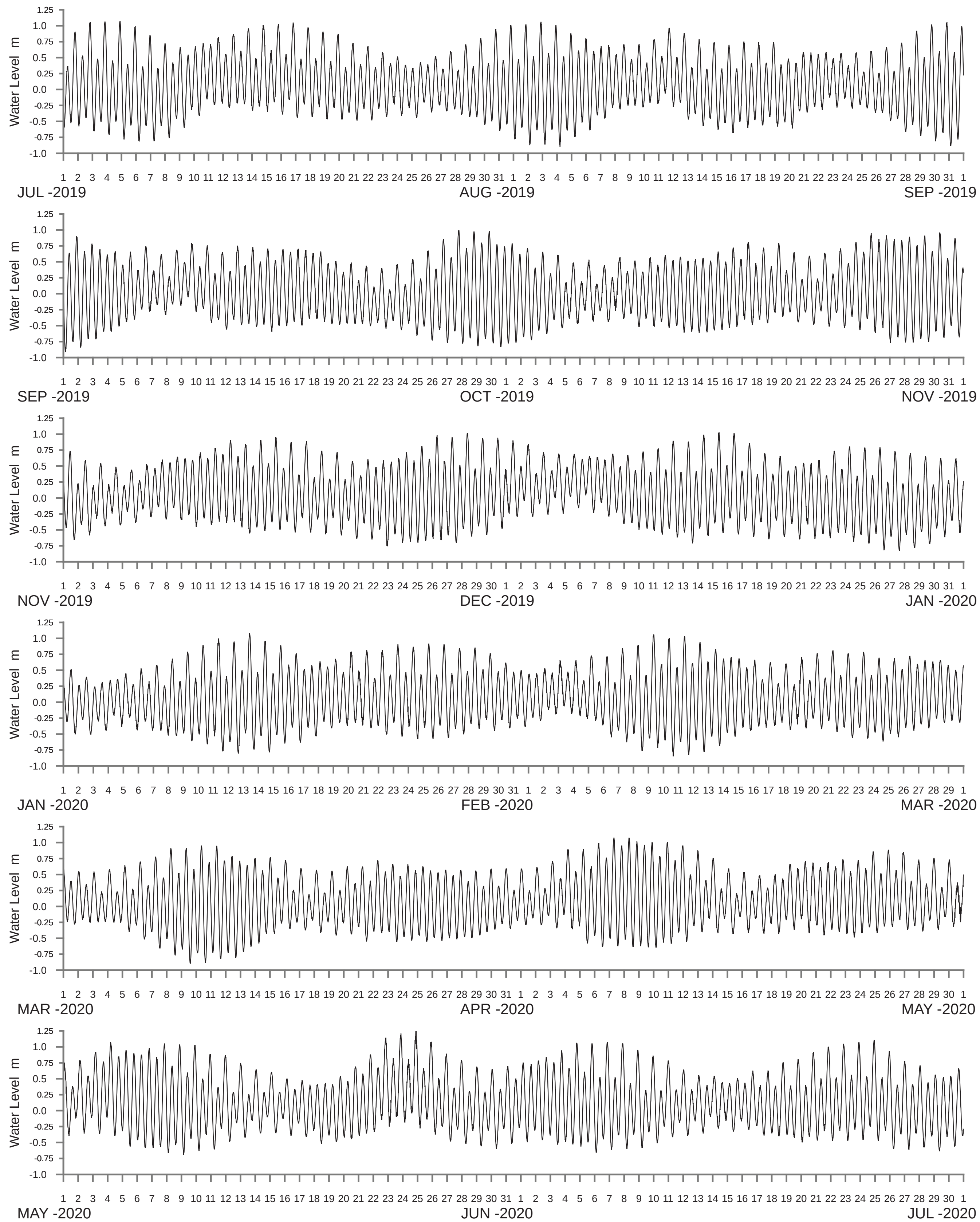
Manly Hydraulics Laboratory

Report MHL2770

Figure

A25

DRAWING 2770-A25.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT

SYDNEY DATA SUMMARY
2019–2020

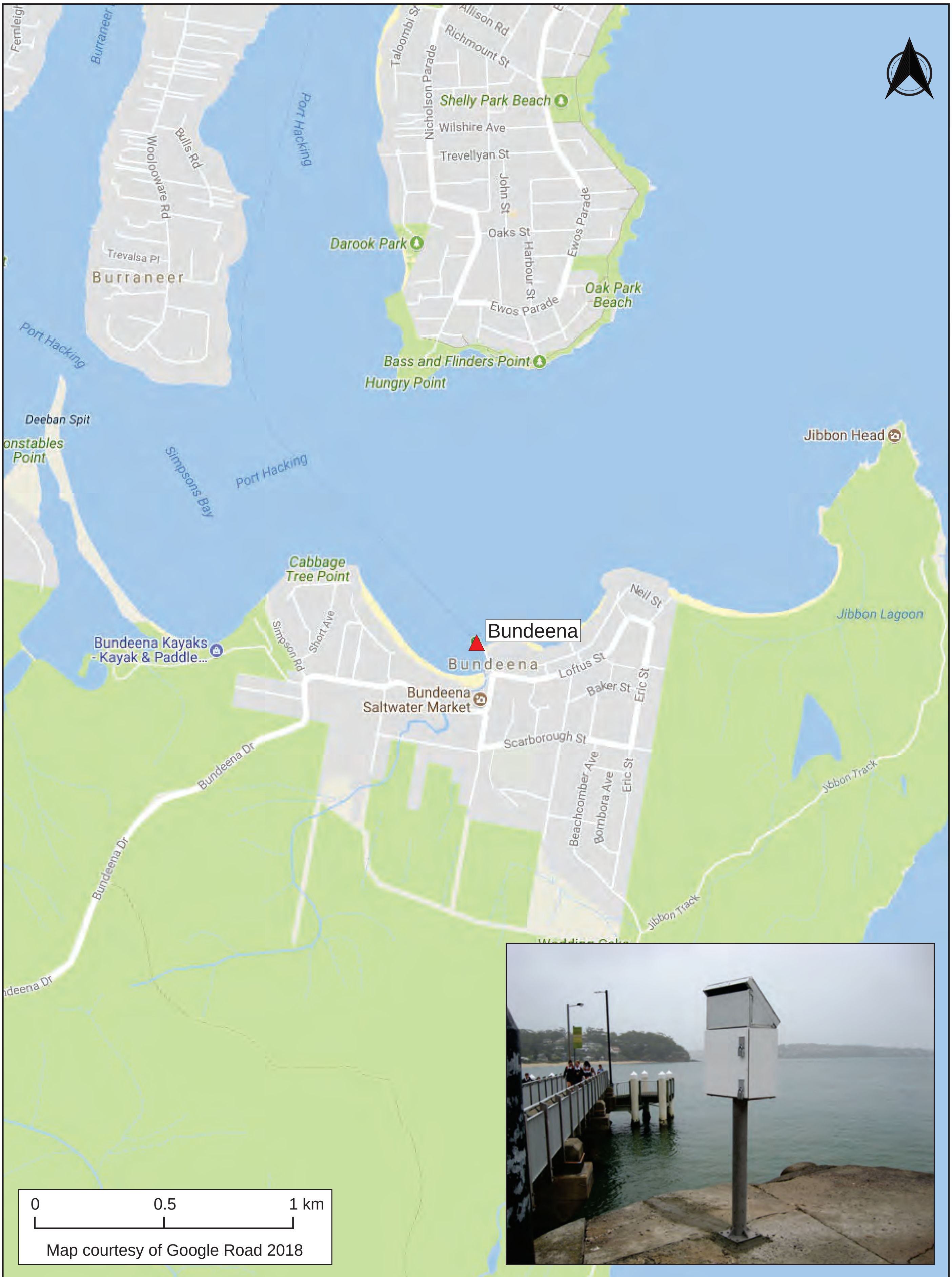
Manly Hydraulics Laboratory

Report MHL2770

Figure

A26

DRAWING 2770-A26.cdr



BUNDEENA
STATION LOCATION

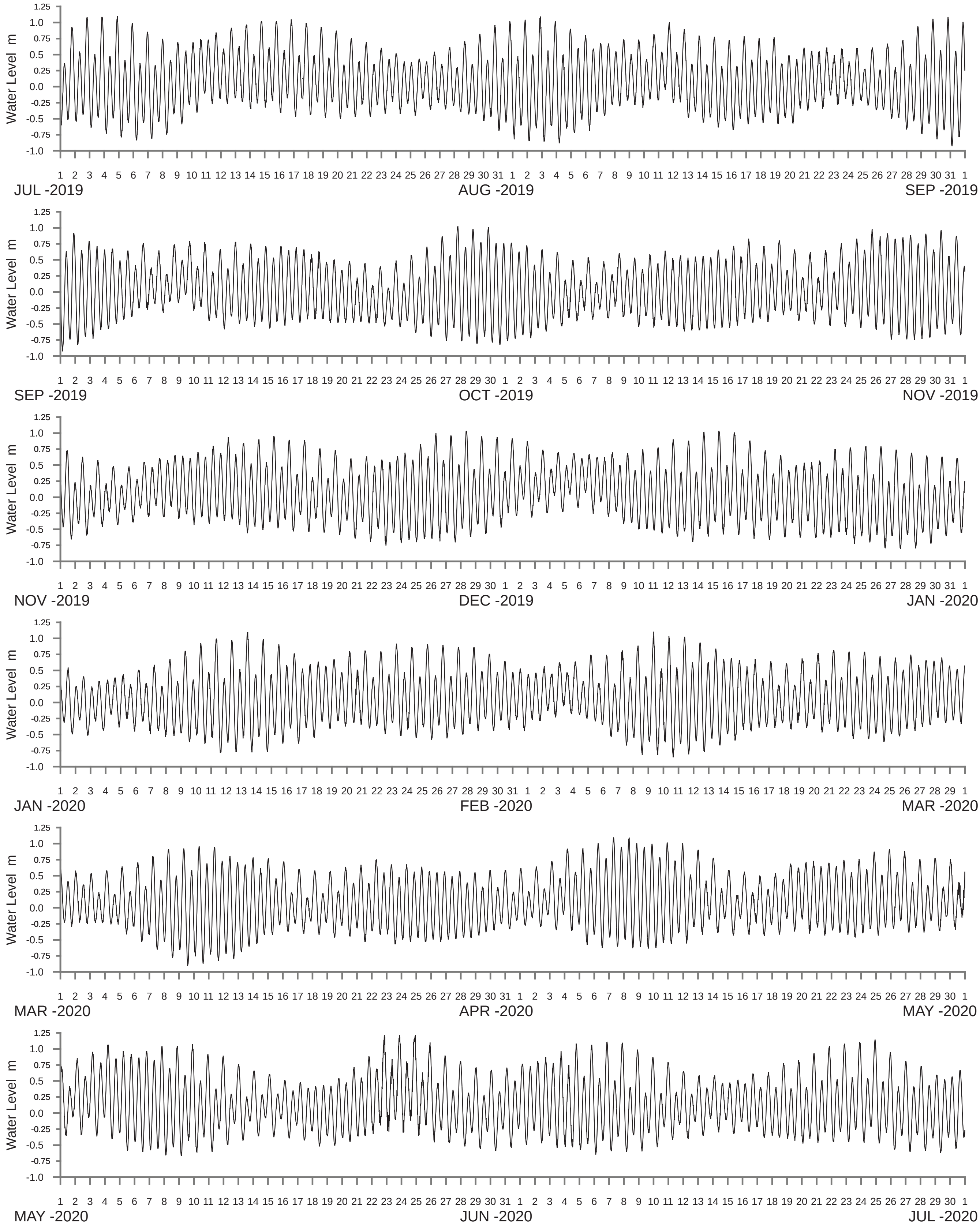
Manly Hydraulics Laboratory

Report MHL2770

Figure

A27

DRAWING 2770-A27.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT

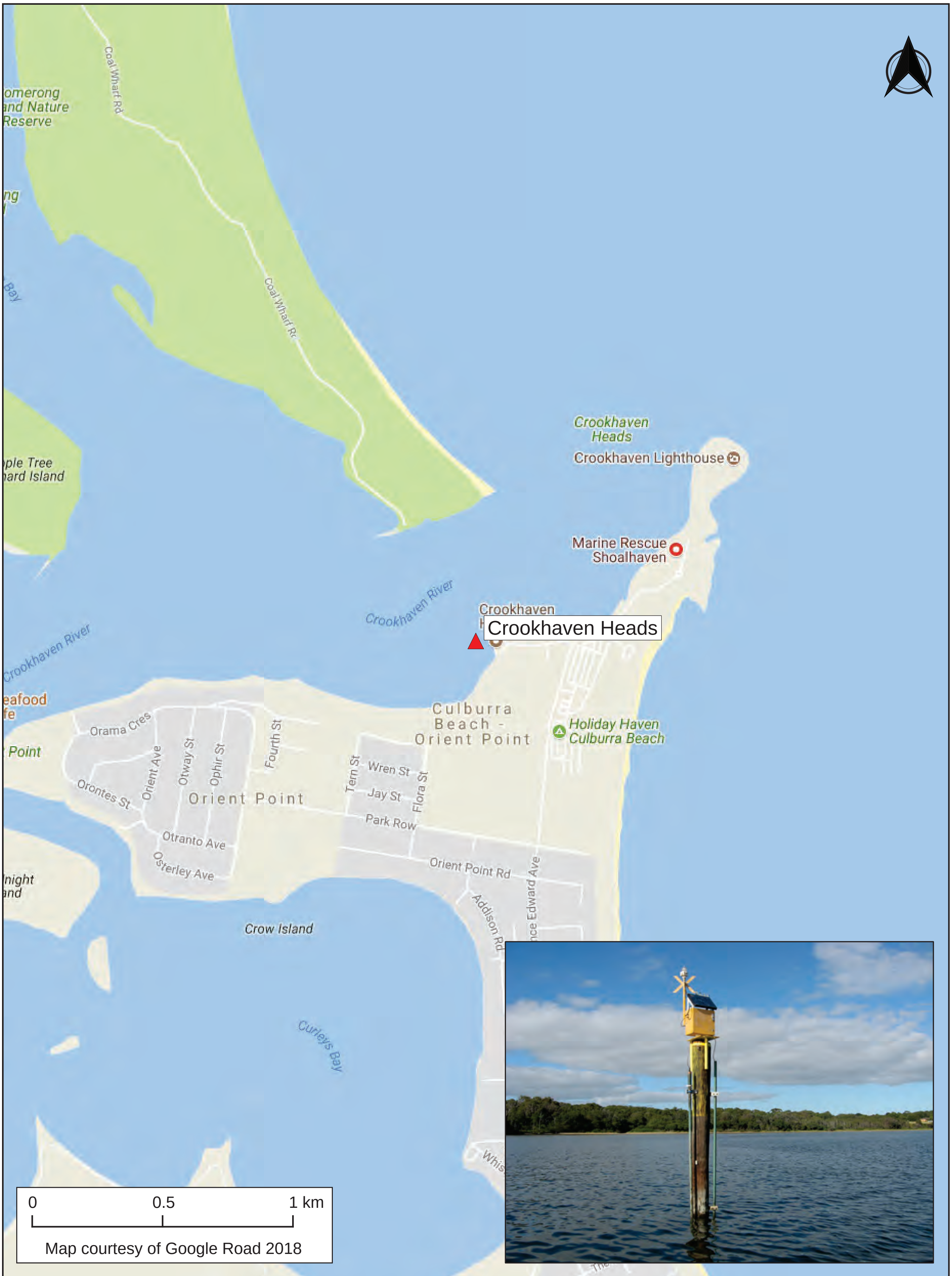
BUNDEENA DATA SUMMARY
2019–2020

Manly Hydraulics Laboratory

Report MHL2770

Figure
A28

DRAWING 2770-A28.cdr



CROOKHAVEN HEADS
STATION LOCATION

NSW GOVERNMENT

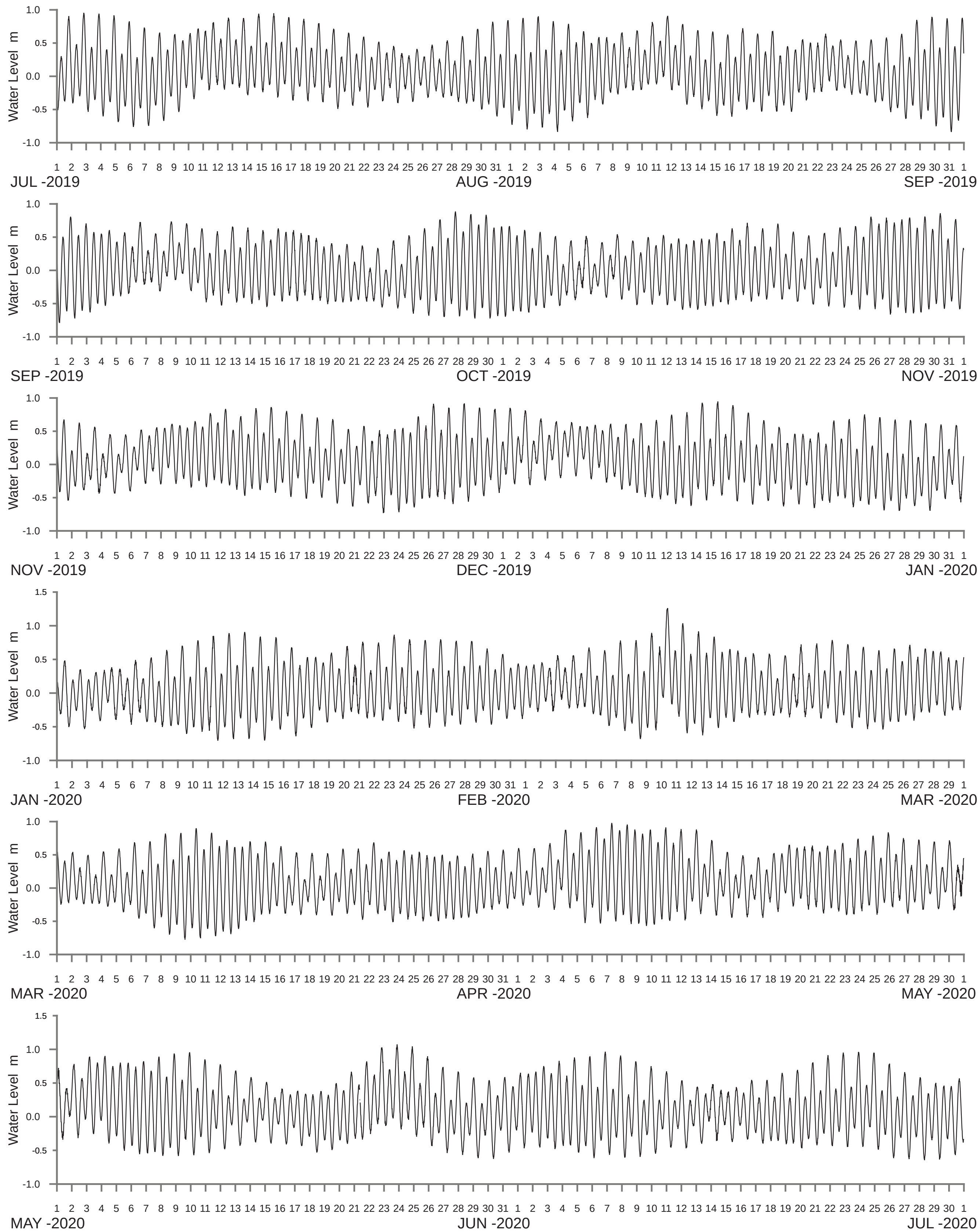
Manly Hydraulics Laboratory

Report MHL2770

Figure

A29

DRAWING 2770-A29.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT

CROOKHAVEN HEADS DATA SUMMARY
2019–2020

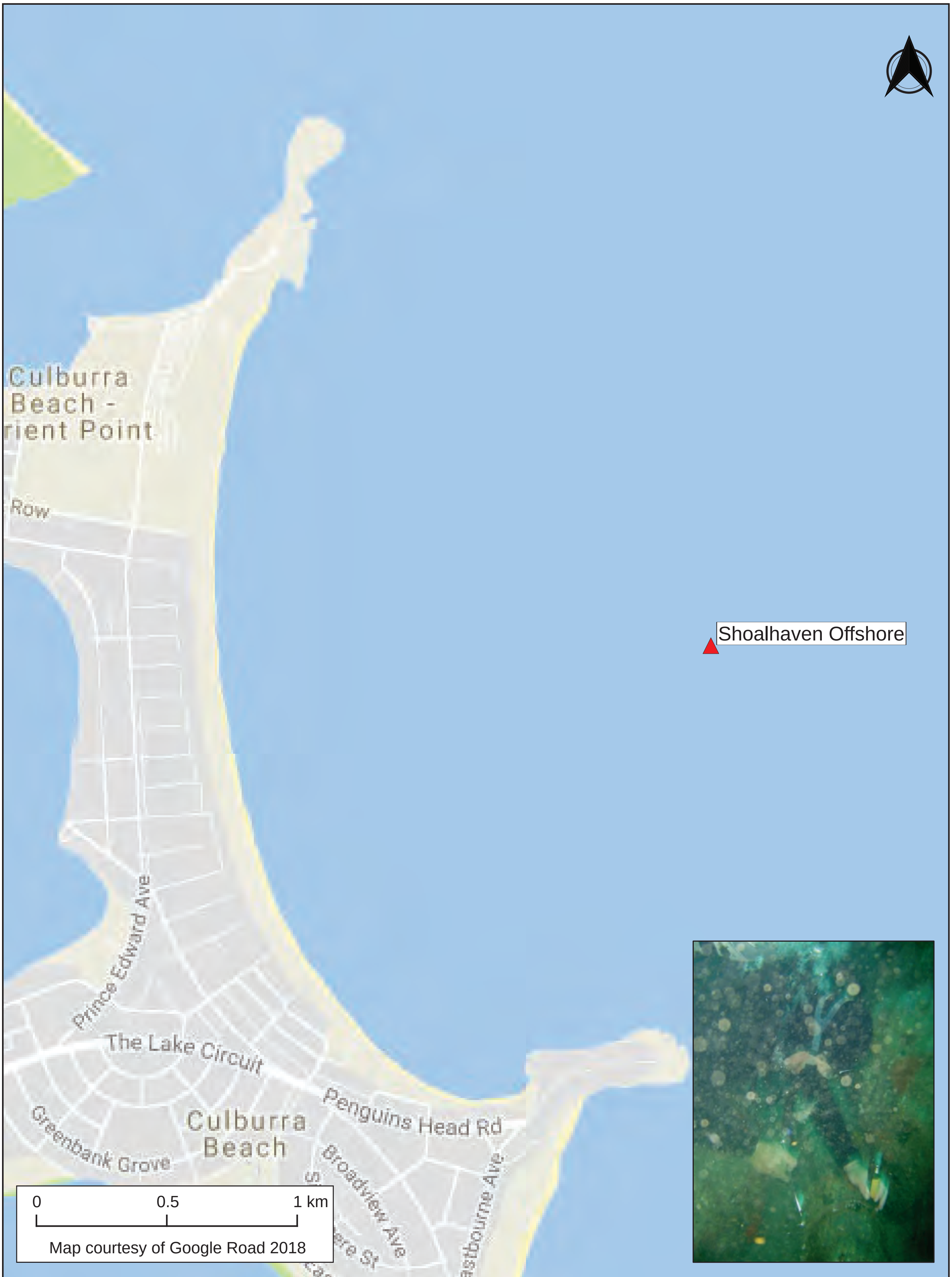
Manly Hydraulics Laboratory

Report MHL2770

Figure

A30

DRAWING 2770-A30.cdr



NSW GOVERNMENT

SHOALHAVEN OFFSHORE
STATION LOCATION

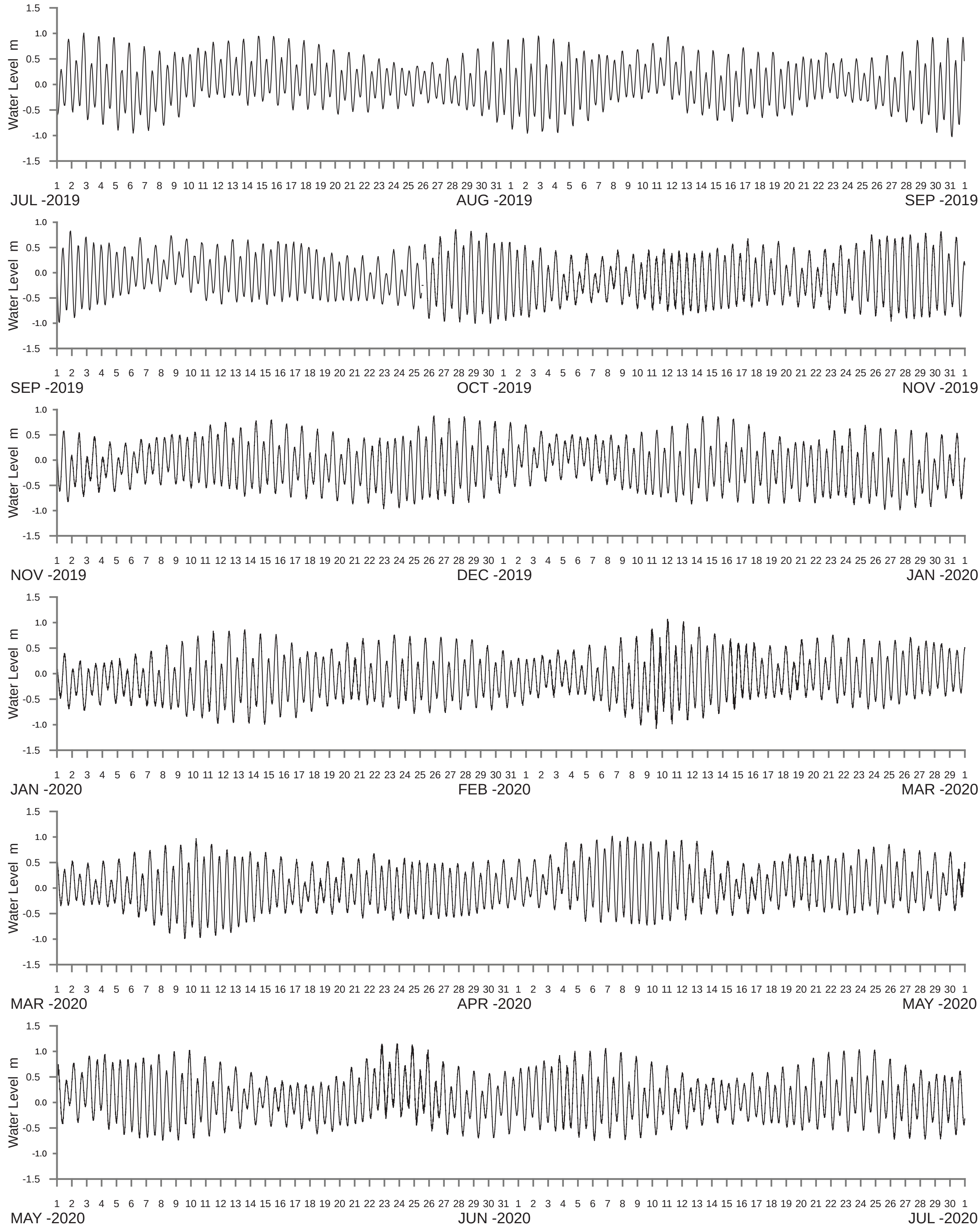
Manly Hydraulics Laboratory

Report MHL2770

Figure

A31

DRAWING 2770-A31.cdr



WATER LEVEL REFERENCED TO MEAN SEA LEVEL

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

NSW GOVERNMENT

SHOALHAVEN OFFSHORE DATA SUMMARY
2019–2020

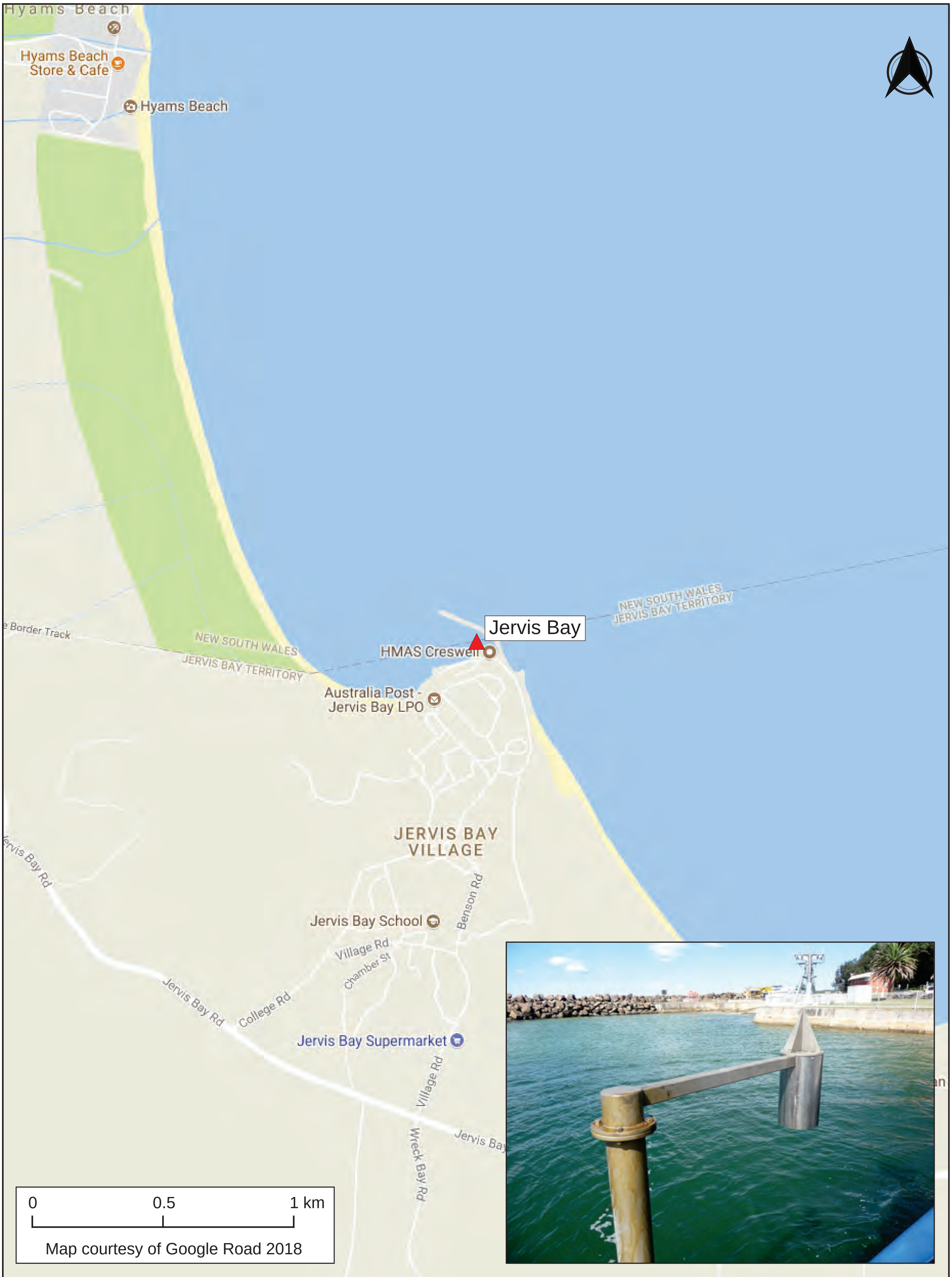
Manly Hydraulics Laboratory

Report MHL2770

Figure

A32

DRAWING 2770-A32.cdr



NSW GOVERNMENT

JERVIS BAY
STATION LOCATION

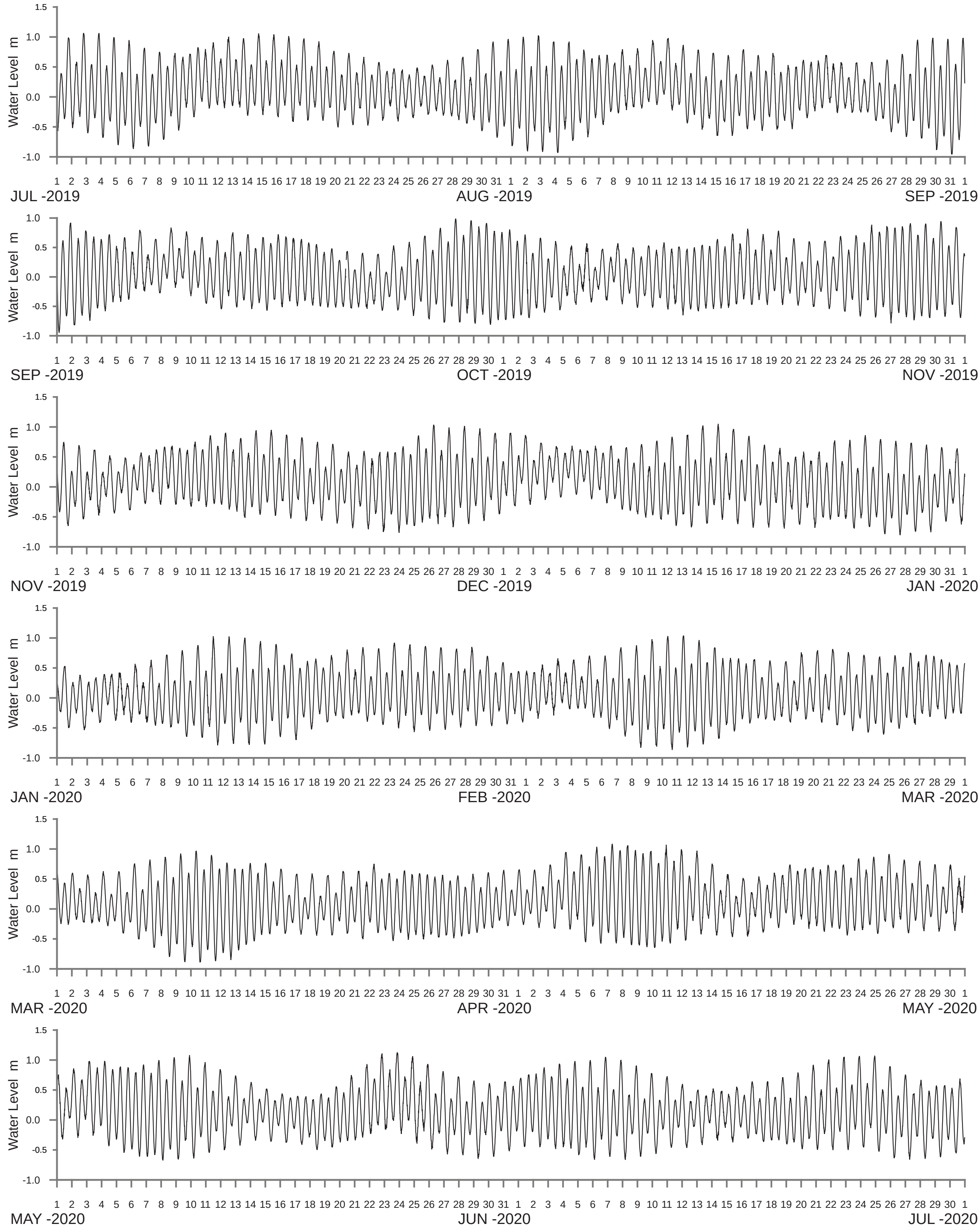
Manly Hydraulics Laboratory

Report MHL2770

Figure

A33

DRAWING 2770-A33.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT

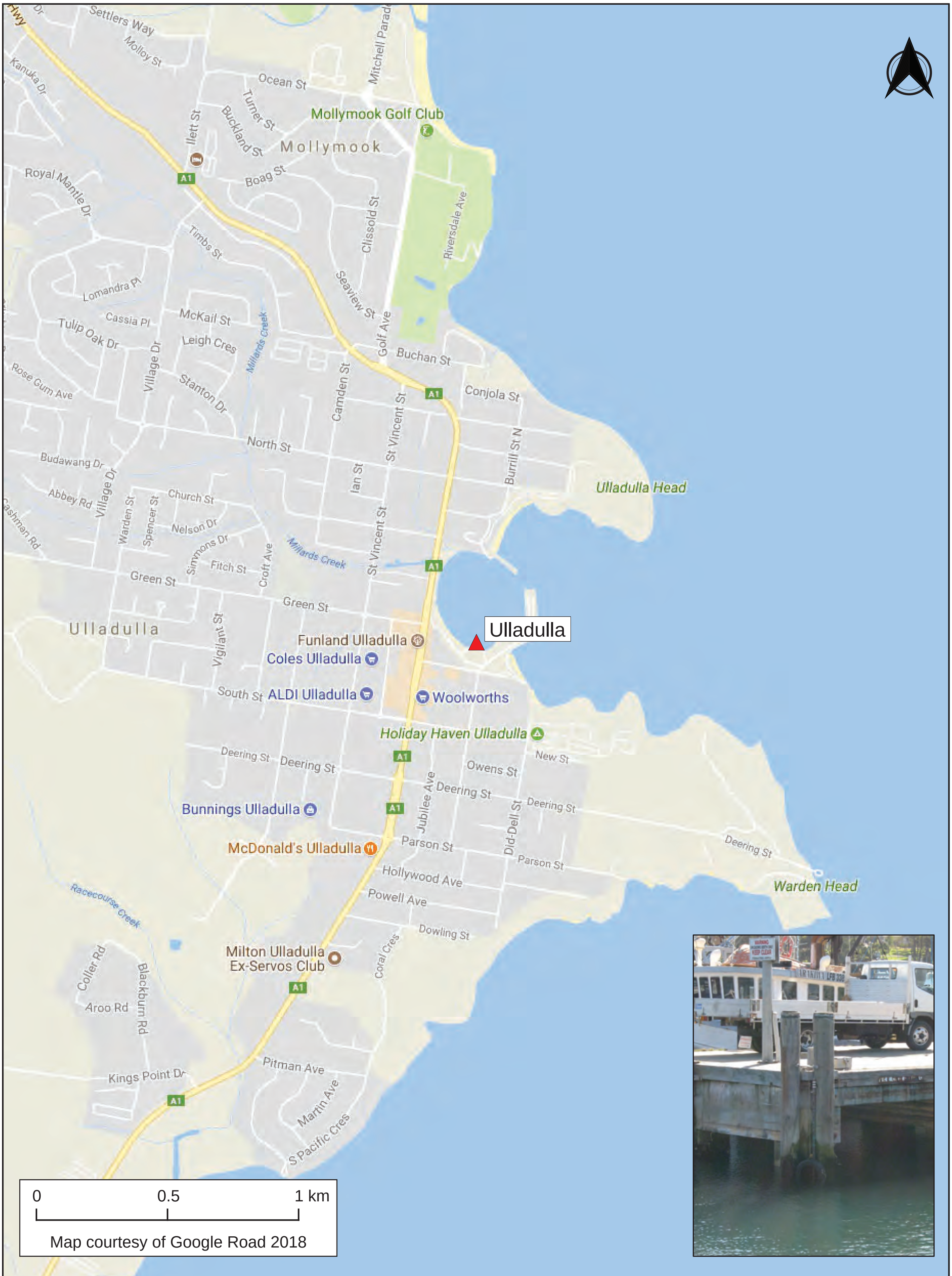
JERVIS BAY DATA SUMMARY
2019–2020

Manly Hydraulics Laboratory

Report MHL2770

Figure
A34

DRAWING 2770-A34.cdr



NSW GOVERNMENT

ULLADULLA
STATION LOCATION

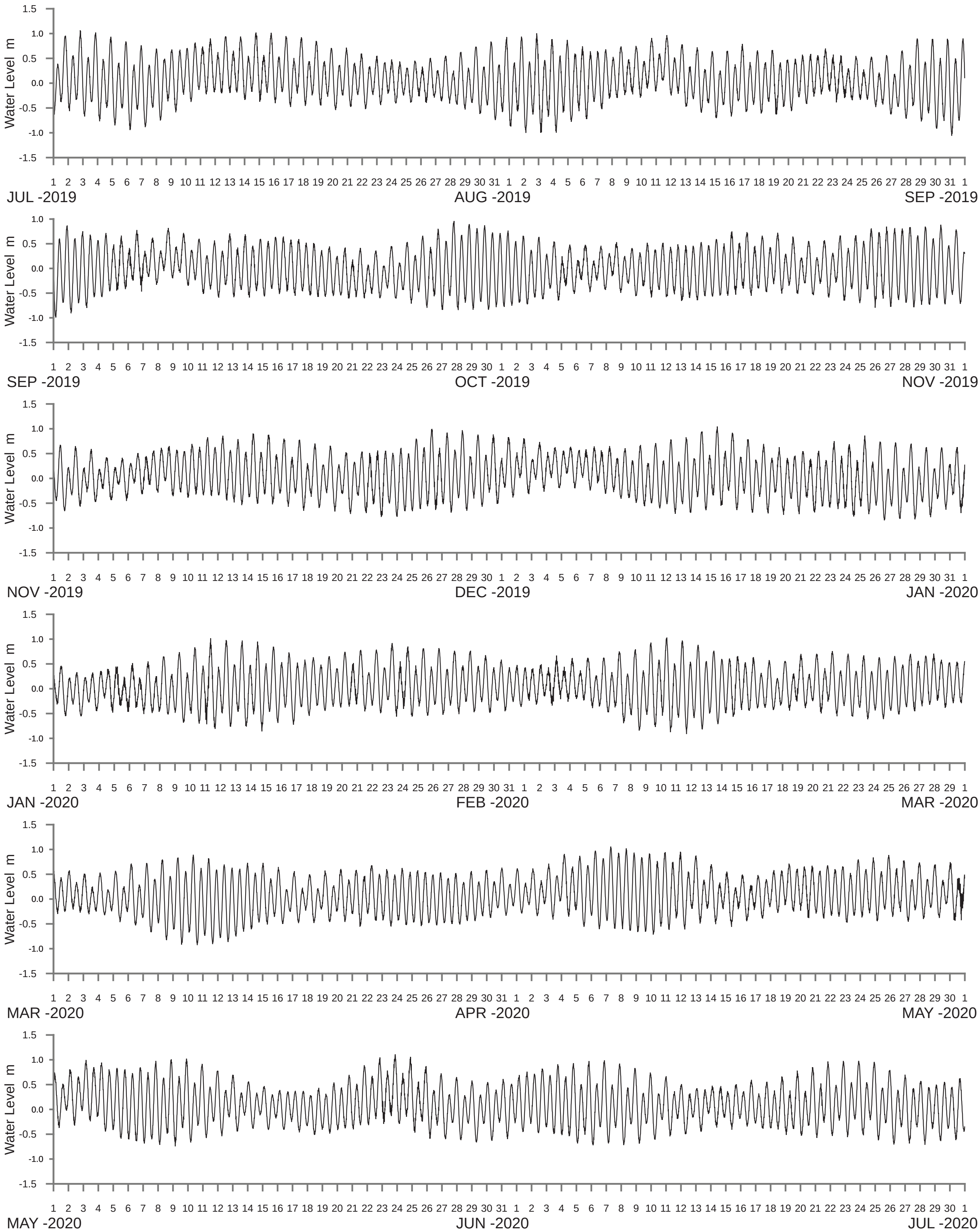
Manly Hydraulics Laboratory

Report MHL2770

Figure

A35

DRAWING 2770-A35.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT

ULLADULLA DATA SUMMARY
2019–2020

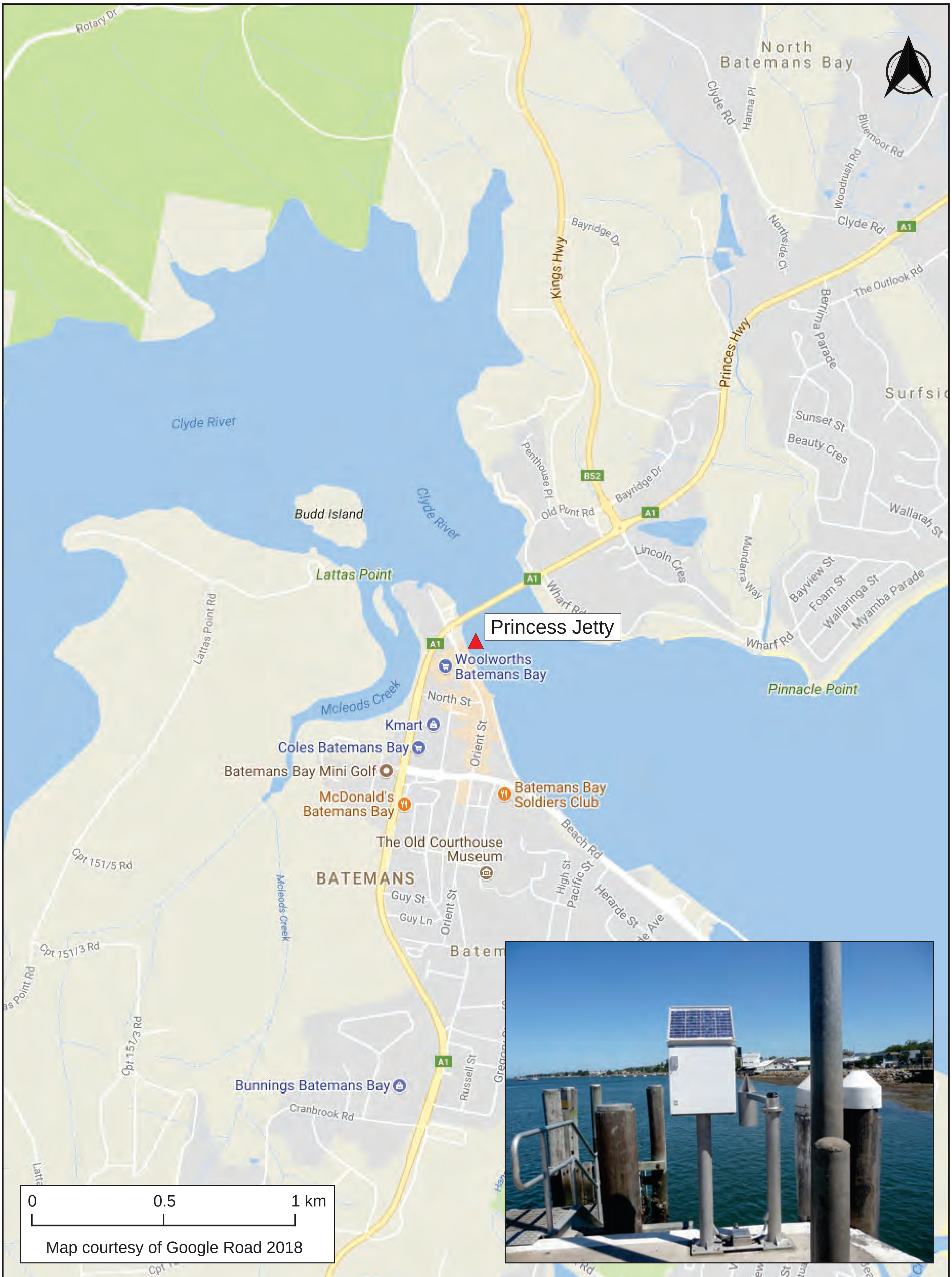
Manly Hydraulics Laboratory

Report MHL2770

Figure

A36

DRAWING 2770-A36.cdr



PRINCESS JETTY
STATION LOCATION

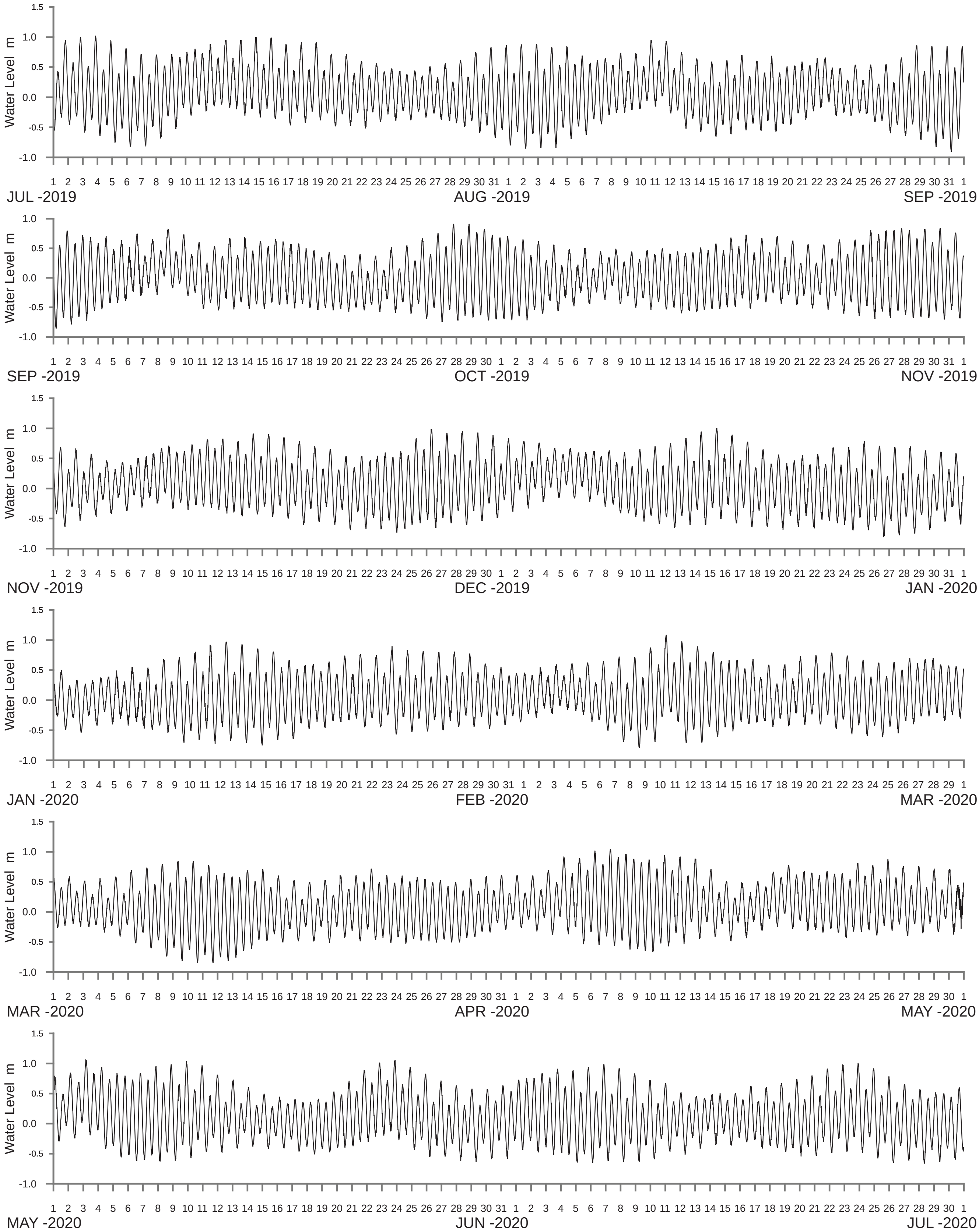
NSW GOVERNMENT

Manly Hydraulics Laboratory

Report MHL2770

Figure A37

DRAWING 2770-A37.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT

PRINCESS JETTY DATA SUMMARY
2019–2020

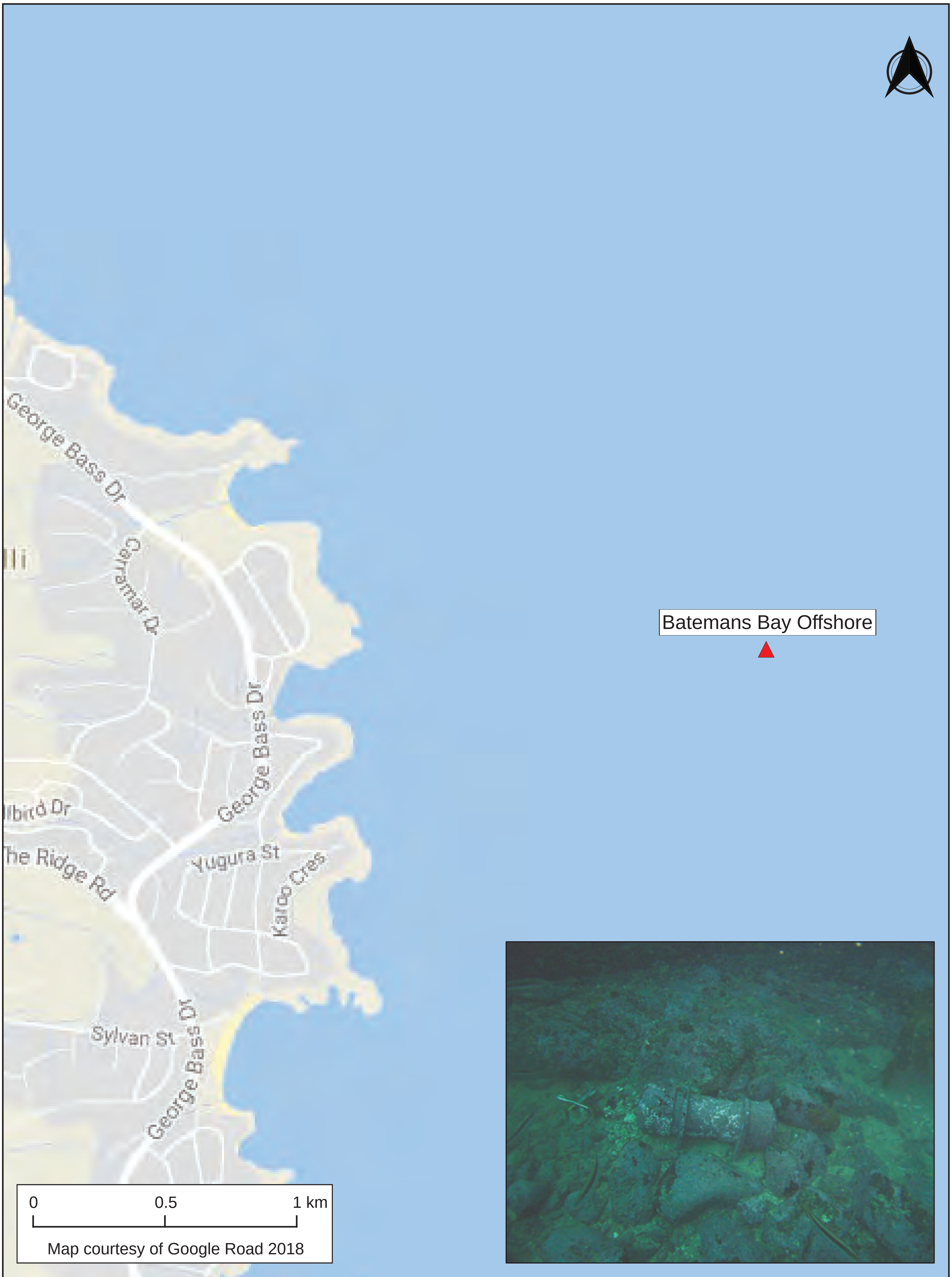
Manly Hydraulics Laboratory

Report MHL2770

Figure

A38

DRAWING 2770-A38.cdr



NSW GOVERNMENT

BATEMANS BAY OFFSHORE
STATION LOCATION

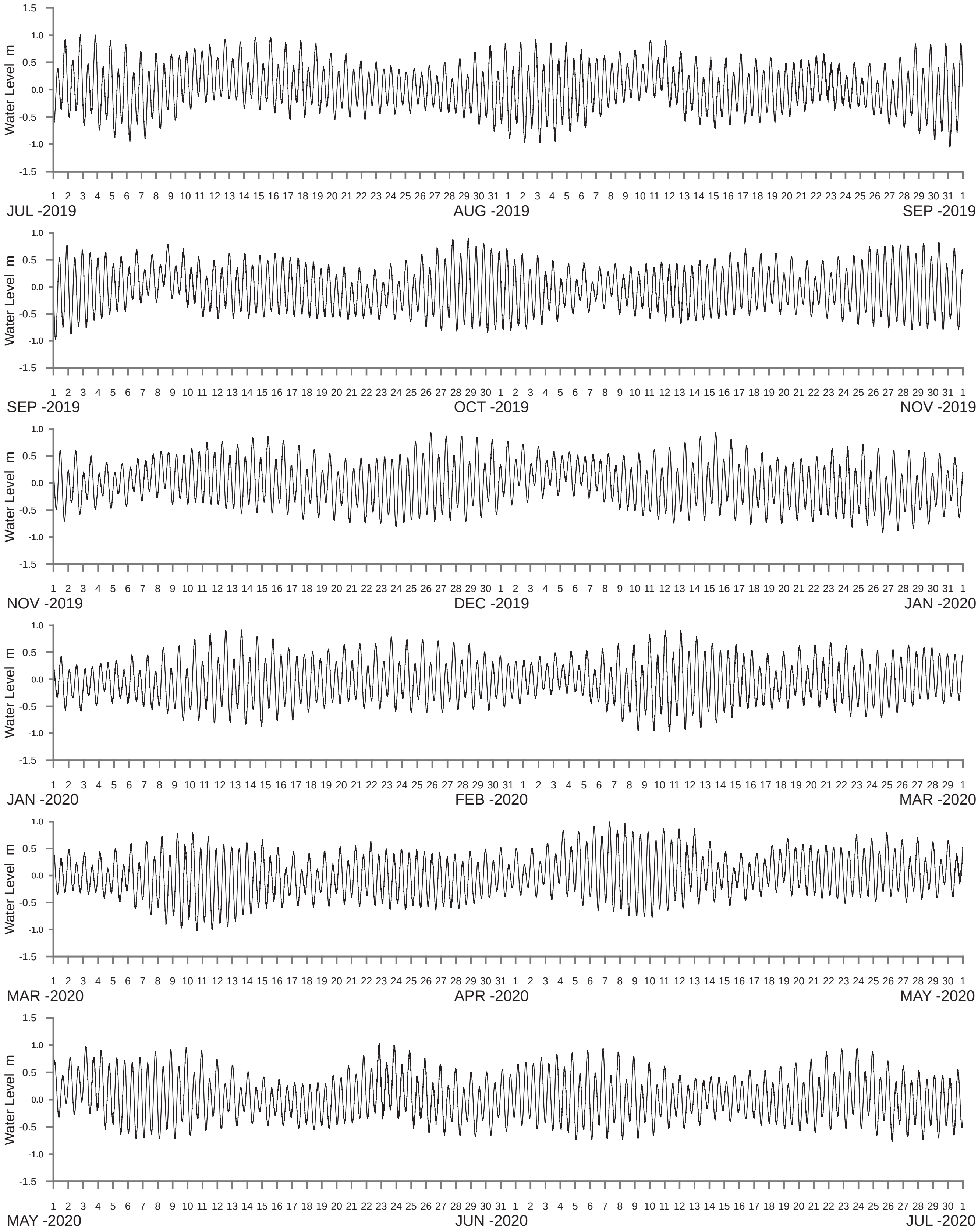
Manly Hydraulics Laboratory

Report MHL2770

Figure

A39

DRAWING 2770-A39.cdr



WATER LEVEL REFERENCED TO MEAN SEA LEVEL

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

BATEMANS BAY OFFSHORE DATA SUMMARY
2019–2020

NSW GOVERNMENT

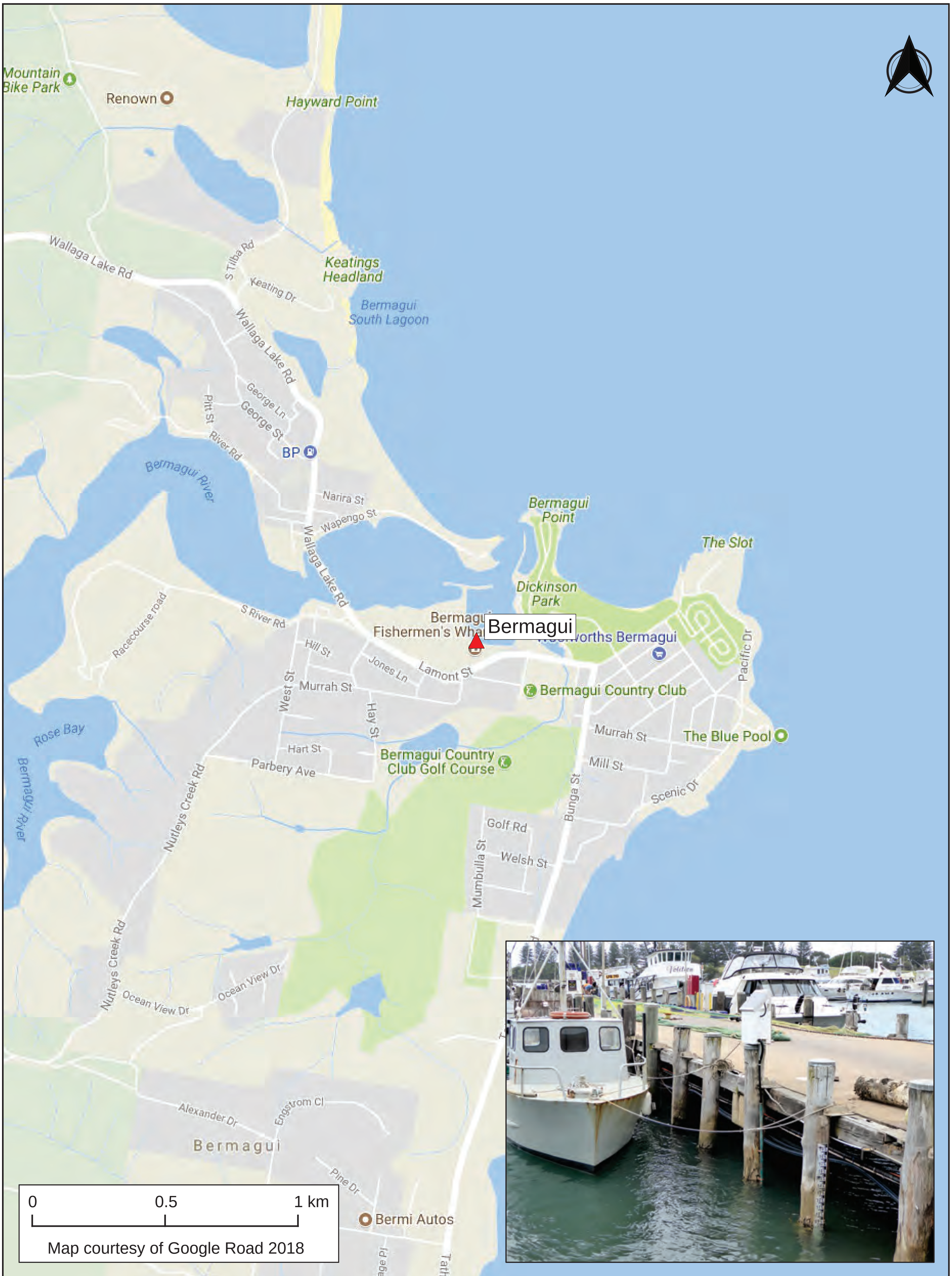
Manly Hydraulics Laboratory

Report MHL2770

Figure

A40

DRAWING 2770-A40.cdr



BERMAGUI
STATION LOCATION

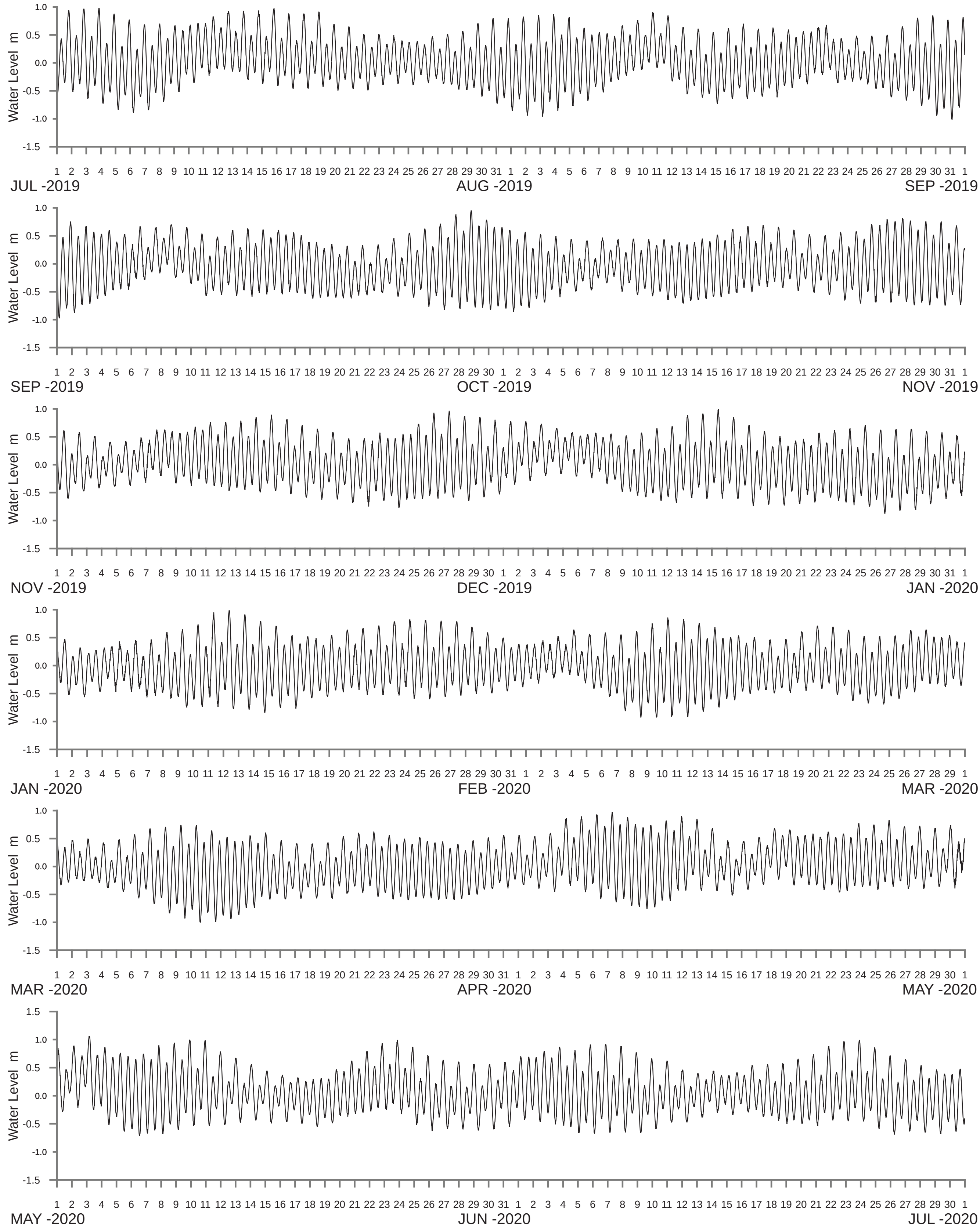
Manly Hydraulics Laboratory

Report MHL2770

Figure

A41

DRAWING 2770-A41.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT

BERMAGUI DATA SUMMARY
2019–2020

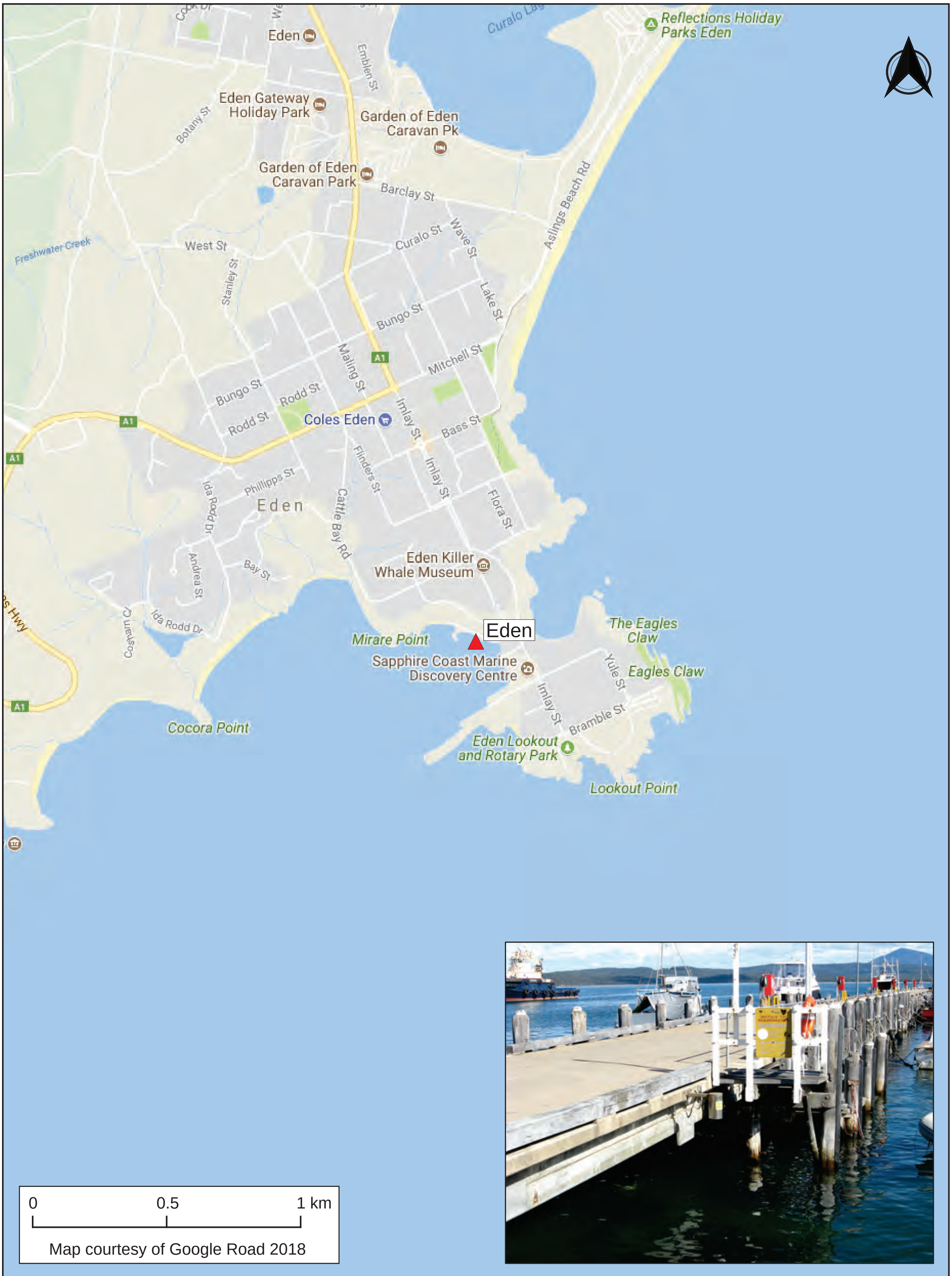
Manly Hydraulics Laboratory

Report MHL2770

Figure

A42

DRAWING 2770-A42.cdr



EDEN
STATION LOCATION

NSW GOVERNMENT

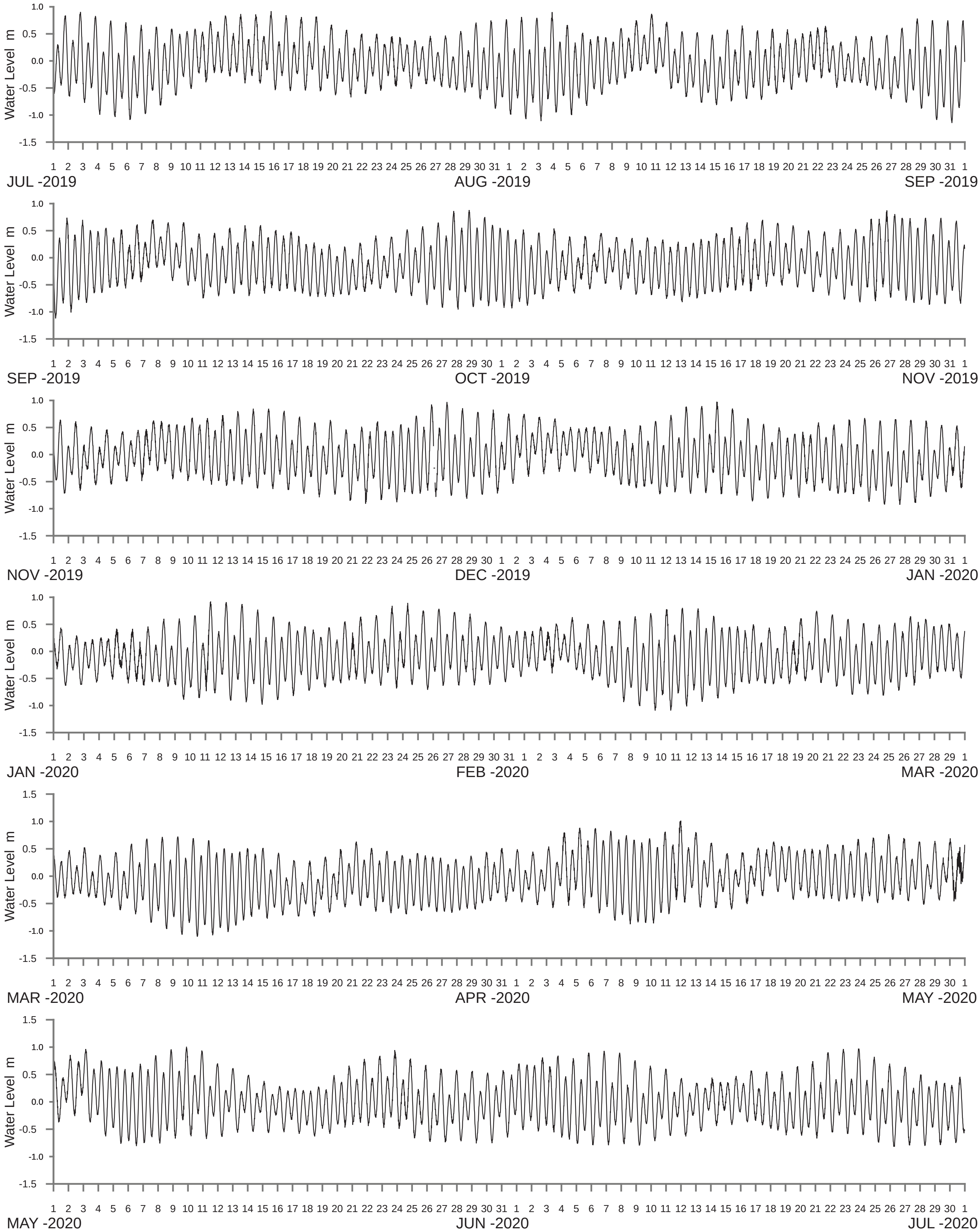
Manly Hydraulics Laboratory

Report MHL2770

Figure

A43

DRAWING 2770-A43.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT

EDEN BOAT HARBOUR DATA SUMMARY
2019–2020

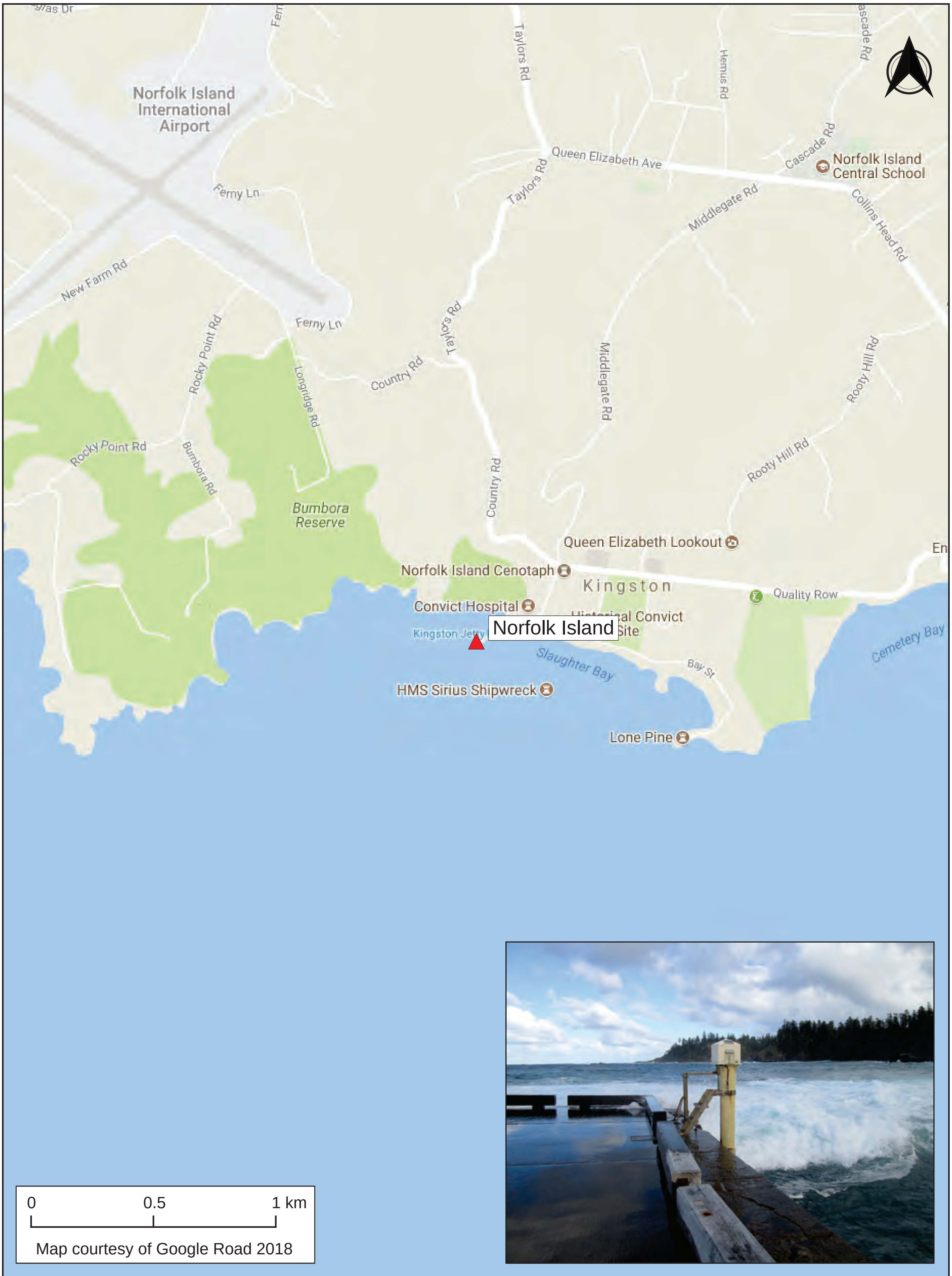
Manly Hydraulics Laboratory

Report MHL2770

Figure

A44

DRAWING 2770-A44.cdr



NSW GOVERNMENT

NORFOLK ISLAND
STATION LOCATION

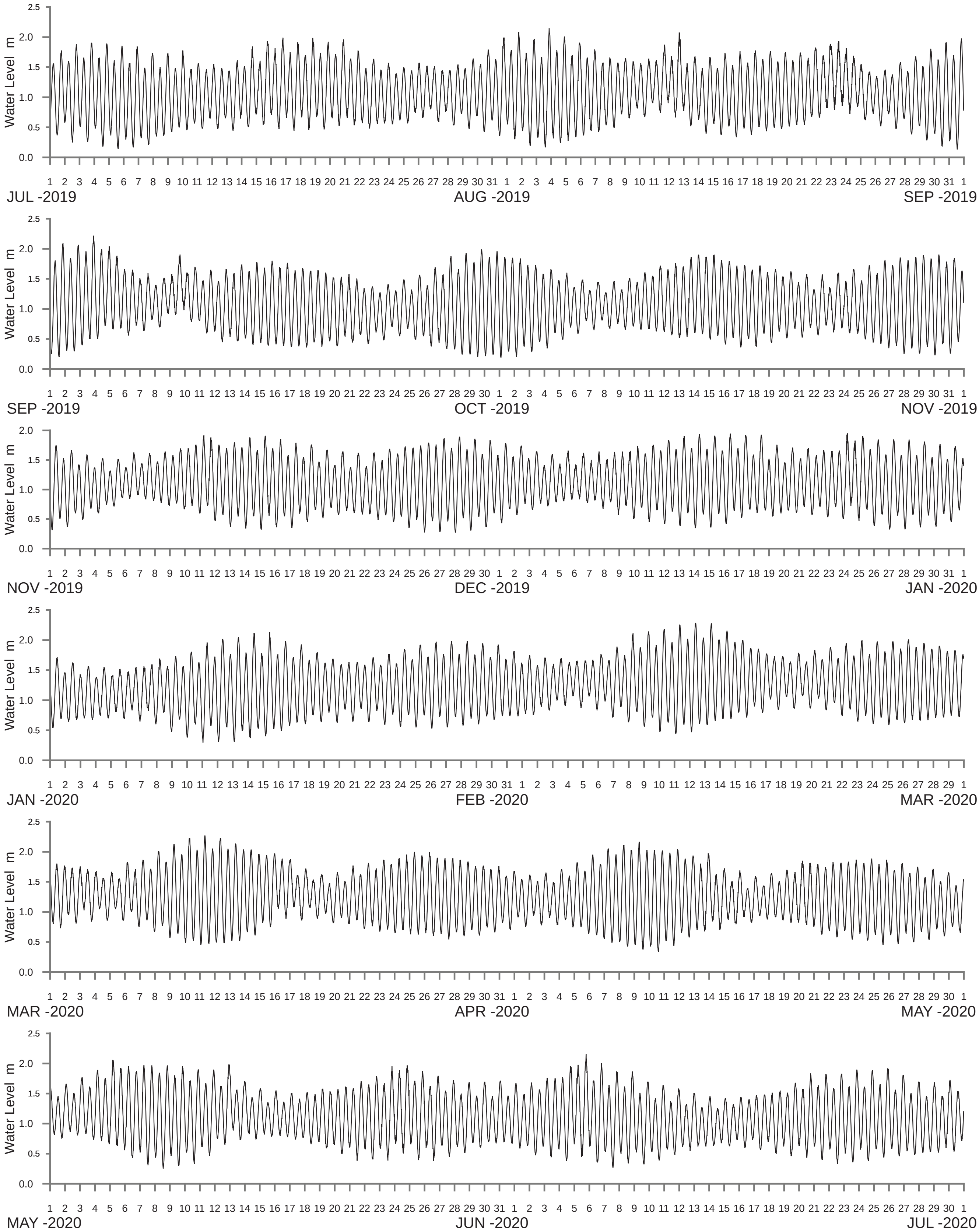
Manly Hydraulics Laboratory

Report MHL2770

Figure

A45

DRAWING 2770-A45.cdr



WATER LEVEL REFERENCED TO LOWEST ASTRONOMICAL TIDE

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

Data provided courtesy of Bureau of Meteorology's National Tidal Unit

NSW GOVERNMENT

NORFOLK ISLAND DATA SUMMARY
2019–2020

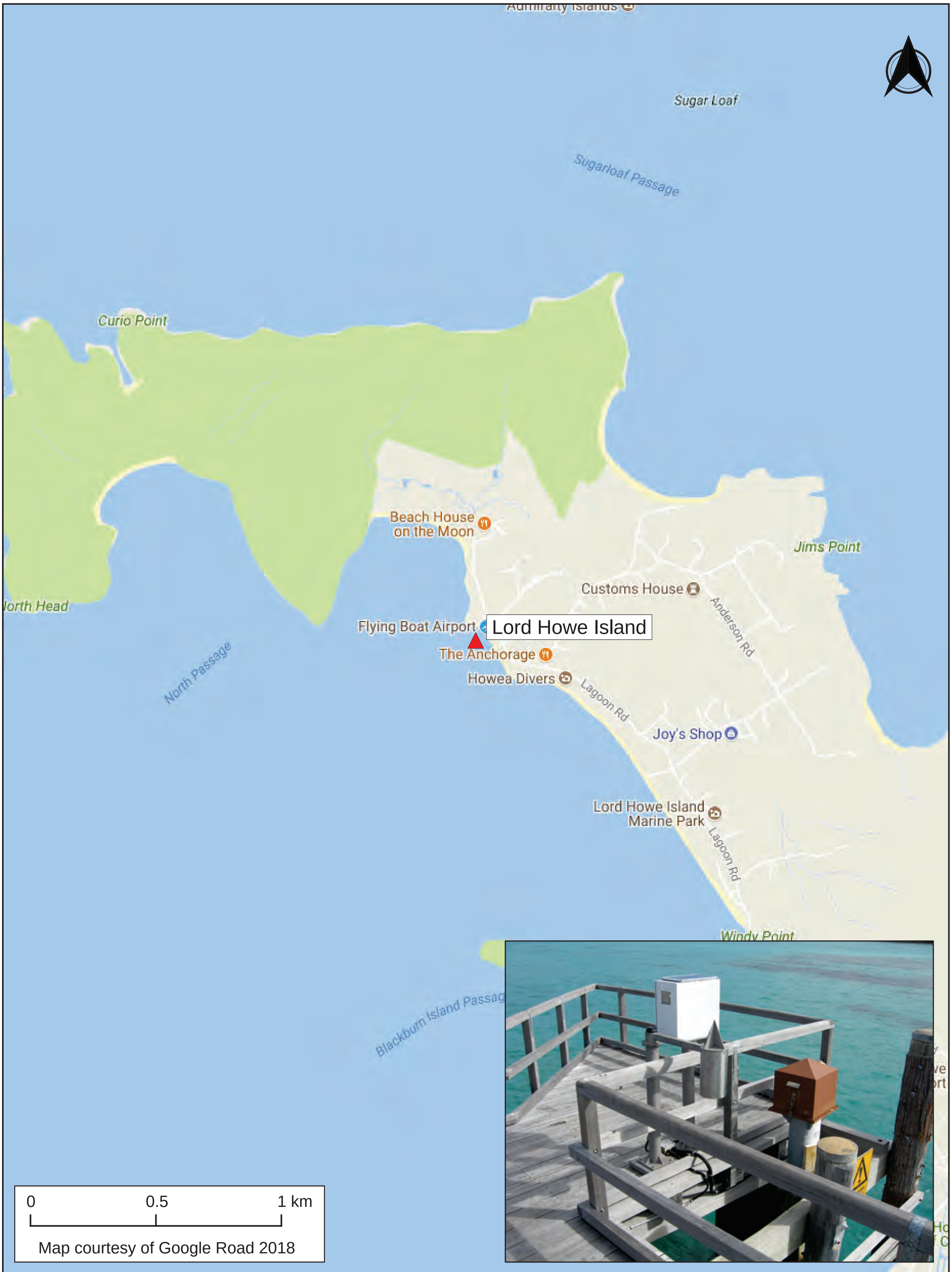
Manly Hydraulics Laboratory

Report MHL2770

Figure

A46

DRAWING 2770-A46.cdr



LORD HOWE ISLAND
STATION LOCATION

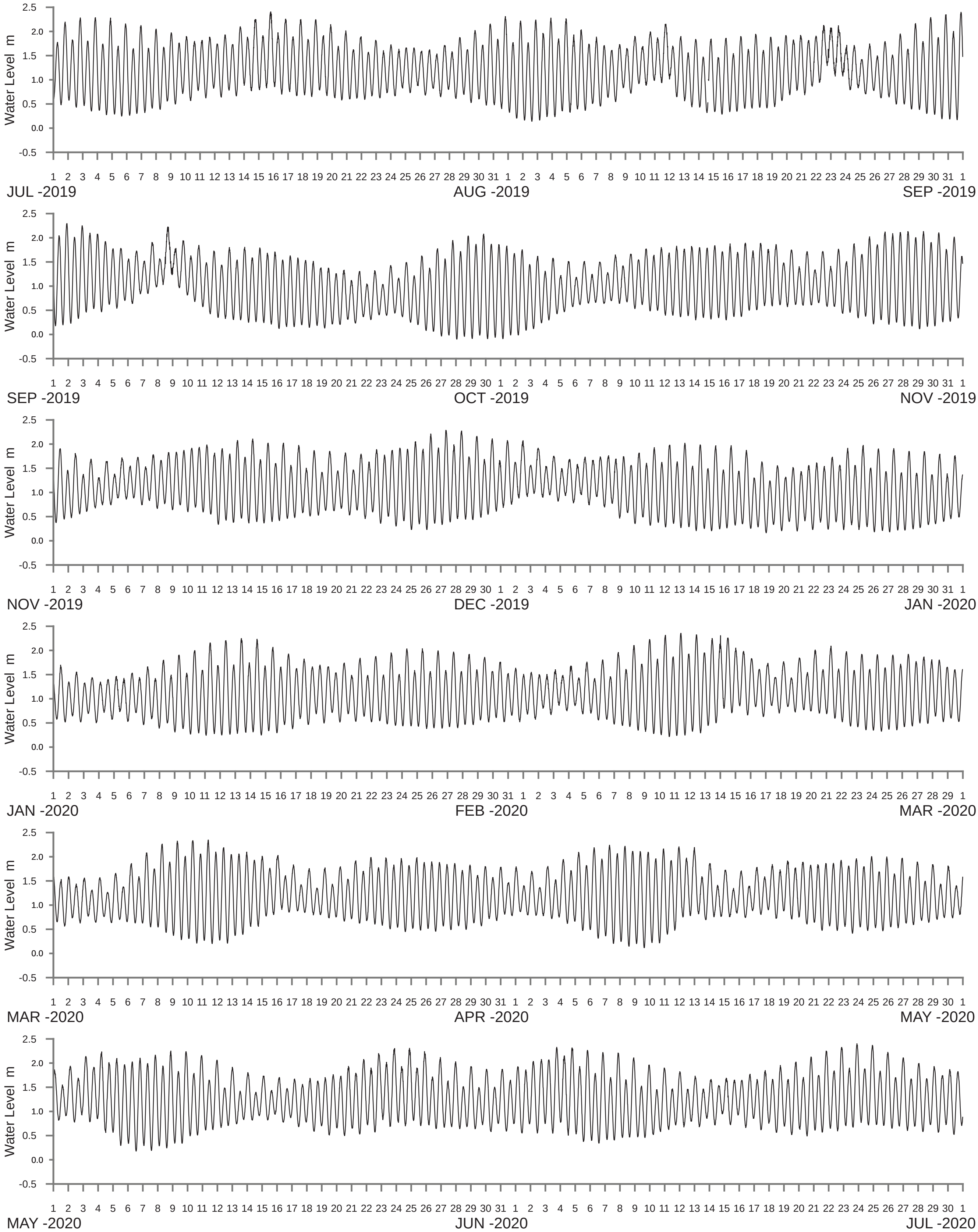
Manly Hydraulics Laboratory

Report MHL2770

Figure

A47

DRAWING 2770-A47.cdr



WATER LEVEL REFERENCED TO LORD HOWE ISLAND DATUM

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

NSW GOVERNMENT

LORD HOWE ISLAND DATA SUMMARY
2019–2020

Manly Hydraulics Laboratory

Report MHL2770

Figure

A48

DRAWING 2770-A48.cdr

Appendix B Current station data

Table B1 Current station digital data

NSW coastal region	Catchment, river or port	Station name	Location	Period of data
North	Tweed River	Tweed Entrance South	South Breakwater	May 2014–ongoing
North	Tasman Sea	Tweed Offshore[1]	Offshore	Dec 1982–ongoing
North	Brunswick River	Brunswick Heads	South Breakwater	Mar 1986–ongoing
North	Richmond River	Ballina Breakwall	South Breakwater	Dec 2008–ongoing
North	Clarence River	Yamba	South Breakwater	Jul 1986–ongoing
North	Coffs Harbour	Coffs Harbour[1]	Inner Harbour Pumpout Jetty	Aug 1996–ongoing
Mid North	Hastings River	Port Macquarie	South Breakwater	Mar 1986–ongoing
Mid North	Tasman Sea	Port Macquarie Offshore[1]	Offshore	Dec 1984–ongoing
Mid North	Crowdy Head Harbour	Crowdy Head[1]	Fishermans Wharf	Jul 1986–ongoing
Mid North	Wallis Lake	Forster	North Breakwater	Jul 1986–ongoing
Central	Port Stephens	Shoal Bay	Public Wharf	Apr 2014–ongoing
Central	Hawkesbury River	Patonga	Public Wharf	Jun 1992–ongoing
Central	Sydney Port Jackson	Sydney	HMAS Penguin Wharf	Sep 1987–ongoing
Central	Sydney Port Jackson	Sydney Backup	HMAS Penguin Wharf	Aug 2010 - ongoing
Central	Port Hacking	Bundeena	Public Wharf	Dec 2014-ongoing
Central	Crookhaven River	Crookhaven Heads	Upstream of Entrance	Mar 1992–ongoing
Central	Tasman Sea	Shoalhaven Offshore	Offshore	Sep 2005–ongoing
Central	Jervis Bay	Jervis Bay	HMAS Creswell	Sep 1989–ongoing
South	Ulladulla Harbour	Ulladulla	Wharf in Harbour	Dec 2007–ongoing
South	Clyde River	Princess Jetty	Public Wharf	Dec 1985–ongoing
South	Tasman Sea	Batemans Bay Offshore	Snapper Island	Sep 2000–ongoing
South	Bermagui River	Bermagui	Inner Harbour	Mar 1987–ongoing
South	Twofold Bay	Eden	Working Jetty	Sep 1986–ongoing
North Tasman Sea	Tasman Sea	Lord Howe Island	Main Wharf	Aug 1994–ongoing

[1] Station has changed location during data period

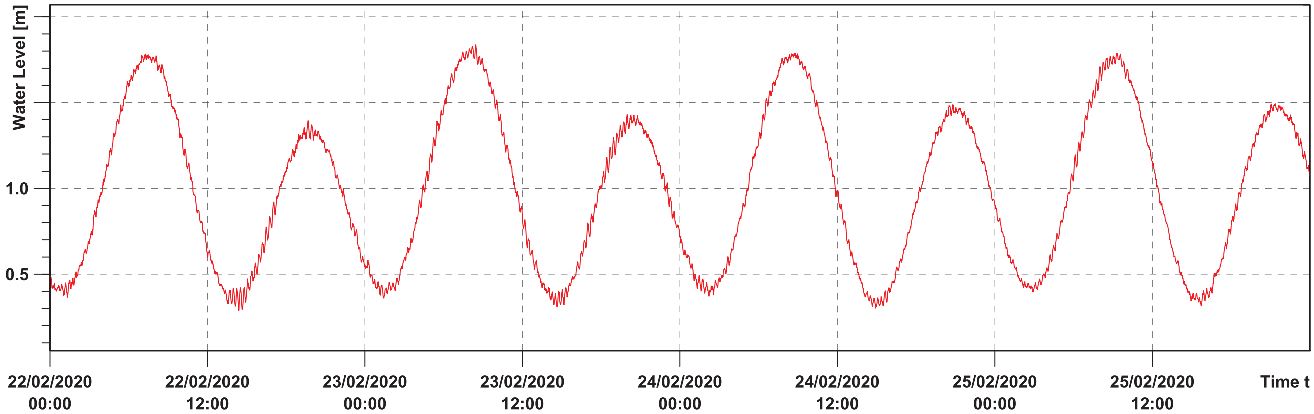
Appendix C Historical tide data

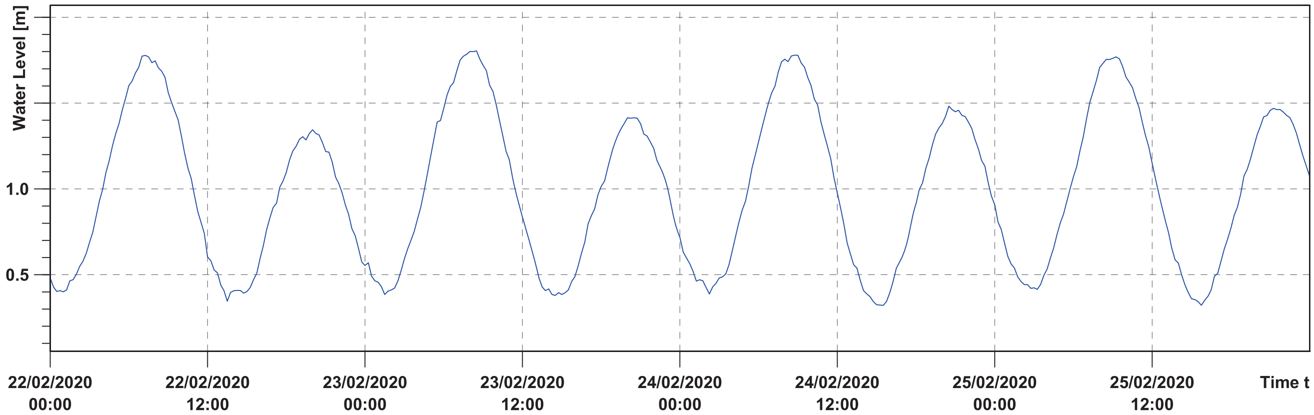
Table C1 Historical tide data

Station Name	Location	Period of record	Location
Tweed Regional	North Breakwater	Feb 1987–Apr 2015	On line
Tweed Regional	Breakwater 201470	1978–1980	On line
Richmond River	Breakwater 202471	1889–1912	HiLos on line
Richmond River	Ballina	1959–1963	Microfiche MHL
Ballina 202470	Half Tide Breakwater	Apr 1986–May 2011	On line
Clarence River	Yamba	1900–1924	HiLos on line
Yamba Offshore	Yamba 204450	Jun 1987–Sep 2009	On line
Clarence River	Iluka 204437	1956–1961	On line
Clarence River	Breakwater	1957–1958	HiLos State Archives
Coffs Harbour	Main harbour	1966–68 and 1969–72	Microfiche MHL
Coffs Harbour	Main harbour	1972–1973	Microfiche MHL
Coffs Harbour	Main harbour	1951–52, 1961–64	HiLos State Archives
Coffs Harbour	Outer harbour 205470	1951–1996	On line
Coffs Harbour	Outer harbour	1953–56, 1957–60	Microfiche MHL
Coffs Harbour	Water Police Jetty Inner Harbour 205470	1990–1996	On line
Macleay River	Entrance 206477	1901–1913	HiLos on line
Crowdy Head	CSIRO 208470	1985–1986	On line
Tomaree	Hospital Jetty 209471	Oct 1985–Apr 2014	On line
Tomaree	Hospital Jetty	1967–1969	HiLos State Archives
Newcastle	Boat harbour 210461	1899–1921	HiLos on line
Newcastle	Breakwater	1946–1961	HiLos State Archives
Port Hacking	Hungry Point	Nov 1987–Feb2015	On line
Port Jackson	Fort Denison 60370	1914–2020	On line
Port Kembla	Harbour	1957–1965	Microfiche State Archives
Port Kembla	Harbour 214480	1987–1992	On line
Jervis Bay	HMAS Creswell 216471	1914–1919	HiLos on line
Jervis Bay	Huskisson 216472	1987–1993	On line
Batemans Bay Offshore	Snapper Island 216451	1986–1990	On line
Batemans Bay Offshore	Offshore 216452	1987–1988	On line (MHL556)
Moruya River	Moruya Heads 217403	1951–1952	HiLos State Archives
Moruya River	Entrance	1951–52, 1987–88	On line
Eden	Snug Cove 220470	1978–1990	On line
Eden	Snug Cove	1954–1956	Microfiche State Archives
Norfolk Island	Kingston Jetty	1994-2015	On line

Fort Denison data courtesy of Sydney Ports Corporation and BoM National Tidal Unit.
Data for Norfolk Island since 2015 provided by Bureau of Meteorology's National Tidal Unit (NTU).

Appendix D Sample outputs





Manly Hydraulics Laboratory

NSW GOVERNMENT

1-MINUTE AND 15-MINUTE SAMPLE DATA PLOTS

Manly Hydraulics Laboratory

Report MHL2770

Figure

D1

DRAWING 2770-Appendix D.cdr

Station Name	Sydney
Station Number	213470
Longitude	151.2585
Latitude	-33.8255
Web	http://www.mhl.nsw.gov.au/Station-213470
Datum	Australian Height Datum
Parameter	Level 1

Date	Time	Value[m]	State of value
22/02/2020	0:00:00	-0.3	55
22/02/2020	0:15:00	-0.339	55
22/02/2020	0:30:00	-0.367	55
22/02/2020	0:45:00	-0.388	55
22/02/2020	1:00:00	-0.375	55
22/02/2020	1:15:00	-0.396	55
22/02/2020	1:30:00	-0.377	55
22/02/2020	1:45:00	-0.373	55
22/02/2020	2:00:00	-0.318	55
22/02/2020	2:15:00	-0.306	55
22/02/2020	2:30:00	-0.272	55
22/02/2020	2:45:00	-0.198	55
22/02/2020	3:00:00	-0.186	55
22/02/2020	3:15:00	-0.094	55
22/02/2020	3:30:00	-0.05	55
22/02/2020	3:45:00	0.03	55
22/02/2020	4:00:00	0.1	55
22/02/2020	4:15:00	0.174	55
22/02/2020	4:30:00	0.242	55
22/02/2020	4:45:00	0.305	55
22/02/2020	5:00:00	0.382	55
22/02/2020	5:15:00	0.443	55
22/02/2020	5:30:00	0.501	55
22/02/2020	5:45:00	0.562	55
22/02/2020	6:00:00	0.61	55
22/02/2020	6:15:00	0.647	55
22/02/2020	6:30:00	0.69	55
22/02/2020	6:45:00	0.719	55
22/02/2020	7:00:00	0.753	55
22/02/2020	7:15:00	0.759	55
22/02/2020	7:30:00	0.763	55
22/02/2020	7:45:00	0.758	55
22/02/2020	8:00:00	0.76	55
22/02/2020	8:15:00	0.717	55
22/02/2020	8:30:00	0.705	55

NSW GOVERNMENT

15-MINUTE SAMPLE DATA FILE

ANALYSIS OF TIDAL OBSERVATIONS

TIME OF ANALYSIS	:	0909:04/12/2020
ANALYSIS PERFORMED BY	:	Executed by maddoxs on 2020-12-04 09:09 using Eden / Level 1 / 01 - Continuous.AHD
STATION LOCATION	:	Twofold Bay at Eden Boat Harbour
STATION NAME	:	Eden
STATION LATITUDE	:	-37 DEG 4 MIN SOUTH
STATION LONGITUDE	:	149 DEG 54 MIN EAST
DATUM	:	AHD
ANALYSIS PERIOD START TIME	:	0000:29/06/2019
ANALYSIS PERIOD FINISH TIME	:	0000:29/06/2020
MID POINT TIME	:	0000:29/12/2019
PERIOD OF ANALYSIS	:	366 DAYS 00 HRS
LOCAL TIME ZONE NAME	:	EASTERN STANDARD TIME
LOCAL TIME FACTOR	:	GMT +10:00 HRS
TIME MERIDIAN	:	-10.08 HRS

TIDAL PLANES IN METRES ABOVE ZERO OF LOCAL GAUGE VALUES

High High Water (Solstices Springs)	H.H.W.(S.S.)	:	0.909
Mean High Water Springs	M.H.W.S.	:	0.513
Mean High Water	M.H.W.	:	0.413
Mean High Water Neaps	M.H.W.N.	:	0.312
Mean Sea Level	M.S.L.	:	-0.046
Mean Low Water Neaps	M.L.W.N.	:	-0.404
Mean Low Water	M.L.W.	:	-0.505
Mean Low water Springs	M.L.W.S.	:	-0.605
Indian Spring Low Water	I.S.L.W.	:	-0.888

TIDAL RANGES IN METRES

Mean Spring Range	(M.H.W.S. - M.L.W.S.)	:	1.118
Mean Neap Range	(M.H.W.N. - M.L.W.N.)	:	0.716
Mean Range	(M.H.W. - M.L.W.)	:	0.917
Range	(H.H.W.(S.S.) - I.S.L.W.)	:	1.798

NSW GOVERNMENT

366-DAY TIDAL ANALYSIS TIDAL PLANES

Manly Hydraulics Laboratory

Report MHL2770

Figure

D3

DRAWING 2770-Appendix D.cdr

MANLY HYDRAULICS LABORATORY

STATION NAME : Sydney
RECORDER TYPE : Ocean Tide Station
A.W.R.C. No. : 213470
DATA START : 01.07.2019
DATA FINISH : 30.06.2020
DATA TOTAL : 11 months 30 days
DATABASE TIME INTERVAL (second): null
THRESHOLD LEVEL (m) : 0.975
DATUM : Australian Height Datum
DATE OF ISSUE : 10:15 08.12.2020
ANALYSIS PERFORMED BY : maddoxs
COMMENTS : Sydney Level 1 01 - Continuous.
AHD event ranking for period
01.07.2019 to 30.06.2020

RANK	PEAK (m)	DATE TIME	START	DURATION (hr)	MAX RISE (m/hr)
1	1.249	24.05.2020 21:45	24.05.2020	2.8	0.774
2	1.210	23.05.2020 21:00	23.05.2020	3.0	0.372
3	1.143	22.05.2020 20:30	22.05.2020	2.5	0.279
4	1.107	24.06.2020 22:30	24.06.2020	2.0	0.241
5	1.082	13.01.2020 10:00	13.01.2020	1.8	0.158
6	1.078	07.04.2020 07:30	07.04.2020	1.8	0.192
7	1.078	25.05.2020 22:15	25.05.2020	2.3	0.306
8	1.076	04.05.2020 04:45	04.05.2020	1.8	0.274
9	1.075	08.04.2020 07:45	08.04.2020	1.8	0.228
10	1.075	06.06.2020 20:45	06.06.2020	1.8	0.167
11	1.073	04.07.2019 21:45	04.07.2019	1.8	0.184
12	1.072	23.06.2020 21:45	23.06.2020	1.8	0.225
13	1.064	03.07.2019 20:45	03.07.2019	1.8	0.142
14	1.062	04.06.2020 18:45	04.06.2020	1.8	0.218
15	1.061	02.08.2019 21:30	02.08.2019	1.5	0.215
16	1.059	09.02.2020 08:30	09.02.2020	1.5	0.216
17	1.056	30.08.2019 20:30	30.08.2019	1.5	0.304
18	1.055	02.07.2019 20:15	02.07.2019	1.8	0.240
19	1.053	07.06.2020 21:45	07.06.2020	1.5	0.177
20	1.052	05.06.2020 19:45	05.06.2020	1.5	0.163
21	1.052	07.05.2020 20:15	07.05.2020	1.3	0.153
22	1.049	16.07.2019 19:45	16.07.2019	1.3	0.198
23	1.048	22.06.2020 21:00	22.06.2020	1.3	0.116
24	1.035	08.05.2020 21:15	08.05.2020	1.3	0.081
25	1.034	11.02.2020 09:45	11.02.2020	1.0	0.062
26	1.028	15.12.2019 10:15	15.12.2019	1.3	0.163
27	1.026	15.07.2019 19:30	15.07.2019	1.3	0.154
28	1.021	01.08.2019 20:30	01.08.2019	1.0	0.142
29	1.019	28.11.2019 09:15	28.11.2019	1.3	0.096
30	1.018	29.08.2019 19:30	29.08.2019	1.3	0.121
31	1.009	31.07.2019 19:30	31.07.2019	1.0	0.080

NSW GOVERNMENT

TIDAL LEVEL RANKING

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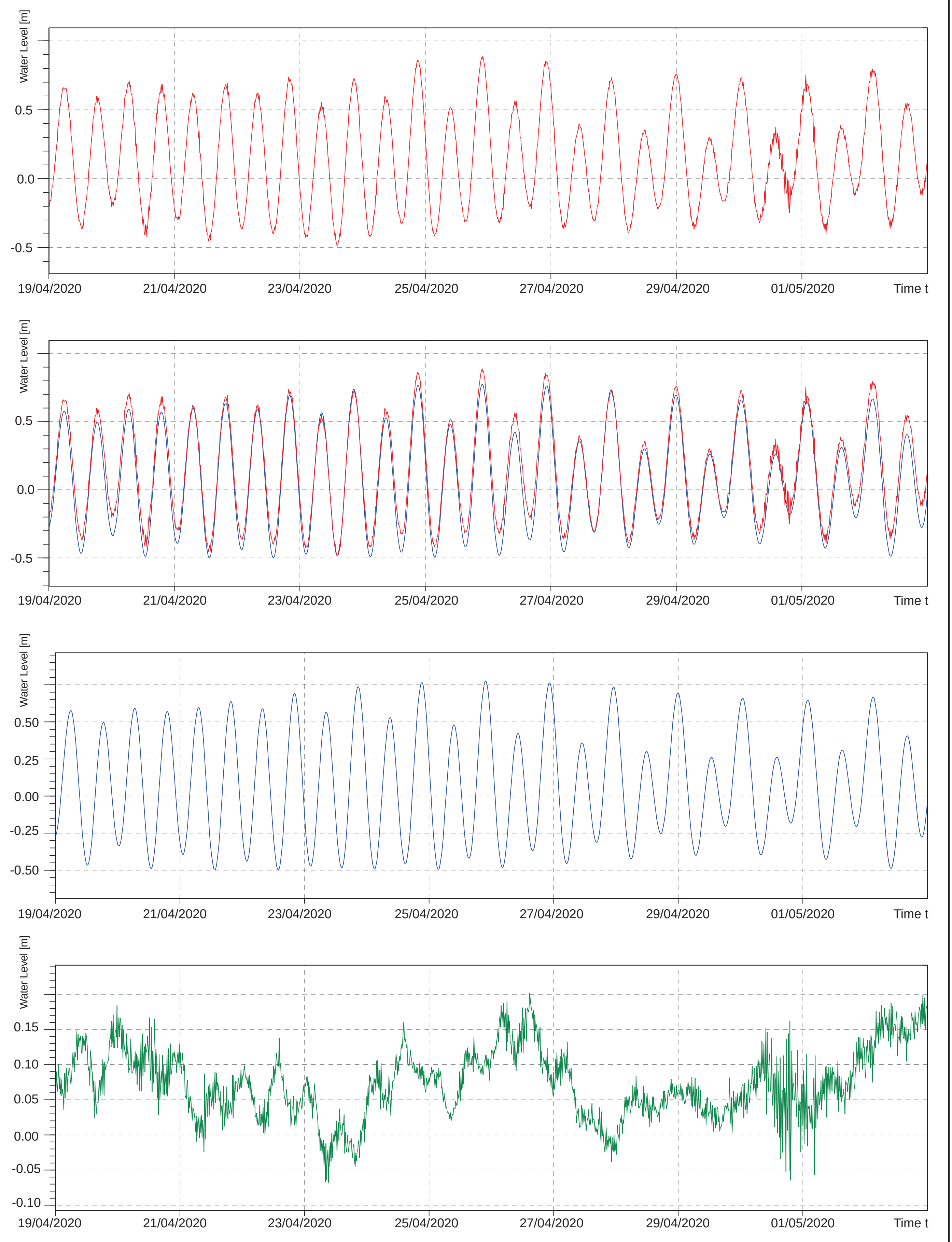
Figure

D4

DRAWING 2770-Appendix D.cdr



NSW GOVERNMENT

SAMPLE TIDAL PREDICTION DATA PLOT

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Report MHL2770

Figure

D5

DRAWING 2770-Appendix D.cdr

Appendix E Glossary of terms

Amplitude (H)	One half of the difference in height between consecutive high water and low water, hence half the tide range.
Australian Height Datum (AHD)	Is a geodetic datum for altitude measurement in Australia. According to Geoscience Australia, in 1971 the mean sea level for 1966-1968 was assigned a value of zero on the Australian Height Datum for 30 tide gauges around the coast of the Australian continent. The resulting datum surface has been termed the Australian Height Datum (AHD) and was adopted by the National Mapping Council as the datum to which all vertical control for mapping is to be referred.
Automatic tide gauge	An instrument that automatically registers the rise and fall of the tide. In some instruments, the registration is accomplished by recording the heights at regular time intervals in digital format.
Benchmark (BM)	A fixed physical object or mark used as reference for a vertical datum. A tidal benchmark is one near a tide station to which the tide staff and tidal datums are referred. A primary benchmark is the principal (or only) mark of a group of tidal benchmarks to which the tide staff and tidal datums are referred.
Chart datum	Chart datum taken to correspond to a low-water elevation, and its depression below mean sea level is represented by the symbol Z.
Coastal boundary	The mean high water line (MHWL) or mean higher high water line (MHHWL) when tidal lines are used as the coastal boundary. Also, lines used as boundaries inland of and measured from (or points thereon) the MHWL or MHHWL.
Constituent	One of the harmonic elements in a mathematical expression for the tide-producing force and in corresponding formulas for the tide or tidal current. Each constituent represents a periodic change or variation in the relative positions of the earth, moon and sun. A single constituent is usually written in the form $y = A \cos (at + á)$, in which y is a function of time as expressed by the symbol t and is reckoned from a specific origin. The coefficient A is called the amplitude of the constituent and is a measure of its relative importance. The angle $(at + á)$ changes uniformly and its value at any time is called the phase of the constituent. The speed of the constituent is the rate of change in its phase and is represented by the symbol a in the formula. The quantity a is the phase of the constituent at the initial instant from which the time is reckoned. The period of the constituent is the time required for the phase to change through 360° and is the cycle of the astronomical condition represented by the constituent.
Digital Recorder (or logger)	An electronic recorder system which stores the information in accessible form, for example, on tape or solid state memory.

Digitise	To translate analog information into digital form i.e. a series of numeric data readable by, and stored within, a digital computer.
Diurnal	Having a period or cycle of approximately one tidal day. Thus, the tide is said to be diurnal when only one high water and one low water occur during a tidal day, and the tidal current is said to be diurnal when there is a single flood and a single ebb period of a reversing current in the tidal day. A rotary current is diurnal if it changes its direction through all points of the compass once each tidal day. A diurnal constituent is one which has a single period in the constituent day. The symbol for such a constituent is the subscript 1.
East Coast Low (ECL)	East Coast Lows (ECL) are intense low-pressure systems which occur on average several times each year off the eastern coast of Australia, in particular southern Queensland, NSW and eastern Victoria. Although they can occur at any time of the year, they are more common during autumn and winter with a maximum frequency in June. East Coast Lows will often intensify rapidly overnight making them one of the more dangerous weather systems to affect the NSW coast. East Coast Lows are also observed off the coast of Africa and America and are sometimes known as east coast cyclones.
Ellipsoid	An idealised model representing the mean sea level of the earth and is used as a computational reference for global position fixing
Encoder	A device that translates tidal movement into computer readable data.
Estuary	An embayment of the coast in which fresh river water entering at its head mixes with the relatively saline ocean water. When tidal action is the dominant mixing agent it is usually termed a tidal estuary. Also, the lower reaches and mouth of a river emptying directly into the sea where tidal mixing takes place. The latter is sometimes called a river estuary.
Extreme high water	The highest elevation reached by the sea as recorded by a tide gauge during a given period.
Extreme low water	The lowest elevation reached by the sea as recorded by a tide gauge during a given period.
Floatwell	A stilling well in which the float of a float-actuated gauge operates. Also known as a stilling well.
Gas purged pressure gauge	A type of analog tide gauge in which gas, usually nitrogen, is emitted from a submerged tube at a constant rate. Fluctuations in hydrostatic pressure due to changes in tidal height modify the emission rate for recording.
Harmonic analysis	Process of measuring or calculating the relative amplitudes and frequencies of all the significant harmonic components present in a given wave form.

Harmonic prediction	Method of predicting tides by combining the harmonic constituents into a single tidal curve. The work is usually performed by electronic digital computer.
Head	The difference in water level at either end of a strait, channel, inlet, etc.
High water (HW)	The maximum height reached by a rising tide. The high water is due to the periodic tidal forces and the effects of meteorological, hydrologic, and/or oceanographic conditions. For tidal datum computational purposes, the maximum height is not considered a high water unless it contains a tidal high water.
High water mark	A line or mark left upon tide flats, beach, or alongshore objects indicating the elevation of the intrusion of high water. The mark may be a line of oil or scum on alongshore objects, or a more or less continuous deposit of fine shell or debris on the foreshore or berm. This mark is physical evidence of the general height reached by wave runup at recent high waters. It should not be confused with the mean high water line or mean higher high water line.
Higher high water (HHW)	The highest of the high waters (or single high water) of any specified tidal day due to the declination A_l effects of the moon and sun.
Higher low water (HLW)	The highest of the low waters of any specified tidal day due to the declination A_l effects of the moon and sun.
Highest Astronomical Tide (HAT)	The highest level which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions; this level may not be reached every year. HAT is not the extreme level which can be reached as storm surges may cause considerably higher levels to occur.
Hydrographic datum	A datum used for referencing depths of water and the heights of predicted tides or water level observations. Same as chart datum. See datum.
Indian spring low water	A datum originated by Professor G. H. Darwin when investigating the tides of India. It is an elevation depressed below mean sea level by an amount equal to the sum of the amplitudes of the harmonic constituents M_2, S_2, K_1, and O_1.
Inverse barometer effect	The inverse response of sea level to changes in atmospheric pressure. A static reduction of 1.005 mb in atmospheric pressure will cause a stationary rise of 1 cm in sea level.
K_1	Lunisolar diurnal constituent. This constituent, with O_1, expresses the effect of the moon's declination. They account for diurnal inequality and, at extremes, diurnal tides. With P_1, it expresses the effect of the sun's declination. Speed = T + h = 15.041,068,6° per solar hour.

King Tide	A non-scientific term used to describe especially high tide events occurring twice a year around early January and early July. They occur when the earth, sun and moon are in alignment and when the sun is closest and furthest from the earth (perihelion and aphelion respectively).
Lambda	Smaller lunar evectional constituent. This constituent, with V_2, U_2, and (S_2), modulates the amplitude and frequency of M_2 for the effects of variation in solar attraction of the moon. This attraction results in a slight pear-shaped lunar ellipse and a difference in lunar orbital speed between motion toward and away from the sun. Although (S_2) has the same speed as S_2, its amplitude is extremely small. Speed = 2T - s + p = 29.455,625,3° per solar hour.
Low water (LW)	The minimum height reached by a falling tide. The low water is due to the periodic tidal forces and the effects of meteorological, hydrologic, and/or oceanographic conditions. For tidal datum computational purposes, the minimum height is not considered a low water unless it contains a tidal low water.
Lower high water (LHW)	The lowest of the high waters of any specified tidal day due to the declination A_l effects of the moon and sun.
Lower low water (LLW)	The lowest of the low waters (or single low water) of any specified tidal day due to the declination A_l effects of the moon and sun.
Lowest Astronomical Tide (LAT)	The lowest level which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions; this level will not be reached every year. LAT is not the extreme level which can be reached as storm surges may cause considerably lower levels to occur.
Lunar tide	That part of the tide on the earth due solely to the moon as distinguished from that part due to the sun.
M_2	Principal lunar semi-diurnal constituent. This constituent represents the rotation of the Earth with respect to the Moon. Speed = 2T - 2s + 2h = 28.984,104,2° per solar hour.
Mean high water (MHW)	A tidal datum. The average of all the high water heights observed over the National Tidal Datum Epoch. For stations with shorter series, simultaneous observational comparisons are made with a control tide station in order to derive the equivalent datum.
Mean low water springs (MLWS)	A tidal datum. Frequently abbreviated spring low water. The arithmetic mean of the low water heights occurring at the time of spring tides observed over the National Tidal Datum Epoch. It is usually derived by taking an elevation depressed below the half-tide level by an amount equal to one-half the spring range of tide, necessary corrections being applied to reduce the result to a mean value.

Mean Sea Level (MSL)	The arithmetic mean of the water level heights at the tidal station observed over a period of time (preferably 19 years).
Modem	A device allowing a computer to be accessed over a telephone line.
Neap tides	Tides of decreased range or tidal currents of decreased speed occurring semi-monthly as the result of the moon being in quadrature. The neap range (Np) of the tide is the average range occurring at the time of neap tides and is most conveniently computed from the harmonic constants. It is smaller than the mean range where the type of tide is either semi-diurnal or mixed and is of no practical significance where the type of tide is predominantly diurnal. The average height of the high waters of the neap tide is called neap high water or high water neaps (MHWN) and the average height of the corresponding low waters is called neap low water or low water neaps (MLWN).
O_1	Lunar diurnal constituent. See K_1. Speed = T - 2s + h = 13.943,035,6° per solar hour.
Phase	1. Any recurring aspect of a periodic phenomenon, such as new moon, high water, flood strength, etc. 2. A particular instant of a periodic function expressed in angular measure and reckoned from the time of its maximum value, the entire period of the function being taken as 360°. The maximum and minimum of a harmonic constituent have phase values of 0° and 180°, respectively.
Pressure Sensor	A pressure transducer sensing device for water level measurement. A relative transducer is vented to the atmosphere and pressure readings are made relative to atmospheric pressure. An absolute transducer measures the pressure at its location. The readings are then corrected for barometric pressure taken at the surface.
Range of tide	The difference in height between consecutive high and low waters. The mean range is the difference in height between mean high water and mean low water. The great diurnal range or diurnal range is the difference in height between mean higher high water and mean lower low water. For other ranges see spring, neap, perigean, apogean, and tropic tides; and tropic ranges.
Relative mean sea level change	A local change in mean sea level relative to a network of benchmarks established in the most stable and permanent material available (bedrock, if possible) on the land adjacent to the tide station location. A change in relative mean sea level may be composed of both an absolute mean sea level change component and a vertical land movement change component, together.
S_2	Principal solar semi-diurnal constituent. This constituent represents the rotation of the Earth with respect to the Sun. Speed = 2T = 30.000,000,0° per solar hour.

Seiche	A stationary wave usually caused by strong winds and/or changes in barometric pressure. It is found in lakes, semi-enclosed bodies of water, and in areas of the open ocean. The period of a seiche in an enclosed rectangular body of water is usually represented by the formula: Period (T) = 2L / square root (gd) in which L is the length, d the average depth of the body of water, and g the acceleration of gravity.
Semi-diurnal	Having a period or cycle of approximately one-half of a tidal day. The predominant type of tide throughout the world is semi-diurnal, with two high waters and two low waters each tidal day. The tidal current is said to be semi-diurnal when there are two flood and two ebb periods each day. A semi-diurnal constituent has two maxima and two minima each constituent day, and its symbol is the subscript 2.
Shallow water constituent	A short-period harmonic term introduced into the formula of tidal (or tidal current) constituents to take account of the change in the form of a tide wave resulting from shallow water conditions. Shallow water constituents include the overtides and compound tides.
Slack water (slack)	The state of a tidal current when its speed is near zero, especially the moment when a reversing current changes direction and its speed is zero. The term also is applied to the entire period of low speed near the time of turning of the current when it is too weak to be of any practical importance in navigation. The relation of the time of slack water to the tidal phases varies in different localities. For a perfect standing tidal wave, slack water occurs at the time of high and of low water, while for a perfect progressive tidal wave, slack occurs midway between high and low water.
Solar tide	1. The part of the tide that is due to the tide-producing force of the sun. 2. The observed tide in areas where the solar tide is dominant. This condition provides for phase repetition at about the same time each solar day.
Solid State	An electronic device composed of components with no moving parts – in this instance, using the electronic properties of solids, as in transistors, semi-conductors and integrated circuits.
Spring high water	Same as mean high water springs (MHWS). See spring tides.
Spring low water	Same as mean low water springs (MLWS). See spring tides.
Spring tides	Tides of increased range or tidal currents of increased speed occurring semi-monthly as the result of the moon being new or full. The spring range (Sg) of tide is the average range occurring at the time of spring tides and is most conveniently computed from the harmonic constants. It is larger than the mean range where the type of tide is either semi-diurnal or mixed, and is of no practical significance where the type of tide is predominantly diurnal. The average height of the high waters of the spring tides is called

	spring high water or mean high water springs (MHWS) and the average height of the corresponding low waters is called spring low water or mean low water springs (MLWS).
Storm surge	The local change in the elevation of the ocean along a shore due to a storm. The storm surge is measured by subtracting the astronomic tidal elevation from the total elevation. It typically has a duration of a few hours. Since wind generated waves ride on top of the storm surge (and are not included in the definition), the total instantaneous elevation may greatly exceed the predicted storm surge plus astronomic tide. It is potentially catastrophic, especially on low-lying coasts with gently sloping offshore topography.
Telemeter	Transmit data to a distant receiving station via a telephone line or by telegraphic means.
Tidal characteristics	Principally, those features relating to the time, range, and type of tide.
Tidal constants	Tidal relations that remain practically constant for any particular locality. Tidal constants are classified as harmonic and non-harmonic. The harmonic constants consist of the amplitudes and epochs of the harmonic constituents, and the non-harmonic constants include the ranges and intervals derived directly from the high and low water observations.
Tidal current	A horizontal movement of the water caused by gravitational interactions between the sun, moon and earth. The horizontal component of the particulate motion of a tidal wave. Part of the same general movement of the sea that is manifested in the vertical rise and fall called tide.
Tidal Epoch	Has been set in Australia as a 20–year period (based on the Lunar Cycle of 18.6 Earth years) over which all recordings of tidal variations and influences are analysed and reviewed.
Tidal Plane	A level of water (often defined by tidal constituents) from which water depths and heights of tides are referenced.
Tide	The periodic rise and fall of the water resulting from gravitational interactions between sun, moon and earth. The vertical component of the particulate motion of a tidal wave. Although the accompanying horizontal movement of the water is part of the same phenomenon, it is preferable to designate this motion as tidal current.
Tide curve	A graphic representation of the rise and fall of the tide in which time is usually represented by the abscissa and height by the ordinate. For a semi-diurnal tide with little diurnal inequality, the graphic representation approximates a cosine curve.
Tide (water level) gauge	An instrument for measuring the rise and fall of the tide (water level).

Tide Tables	Tables which give daily predictions of the times and heights of high and low waters. These predictions are usually supplemented by tidal differences and constants through which predictions can be obtained for numerous other locations.
Tsunami	A shallow water progressive wave, potentially catastrophic, caused by an underwater earthquake or volcano.
Universal time (UTC)	Same as Greenwich mean time (GMT).
Z_0	Symbol recommended by the International Hydrographic Organisation to represent the elevation of mean sea level above chart datum

Appendix F Publications of interest

Data Reports

MHL Annual Ocean Tide Levels Summaries available from 1986–87 to 2018–2019
MHL Report Nos. 515 (86–87), 544 (87–88), 563 (88–89), 585 (89–90), 602 (90–91), 628 (91–92), 658 (92–93), 697 (93–94), 732 (94–95), 777 (95–96), 876 (96–97), 947 (97–98), 1013 (98–99), 1069 (99–00, 1129 (00–01), 1205 (01–02), 1277 (02–03), 1347 (03–04), 1423 (04–05), 1512 (05–06), 1764 (06–07), 1848 (07–08), 1933 (08–09), 2010 (09–10), 2089 (10–11), 2158 (11–12), 2219 (12–13), 2292 (13–14), 2384 (14–15), 2475 (15–16), 2574 (16–17), 2618 (17–18), 2693 (18–19).

Manly Hydraulics Laboratory 1989, *Comparison of Tide Levels Between Fort Denison and Middle Harbour, Sydney Harbour,* Report No. MHL558.

Manly Hydraulics Laboratory 1998, *Tweed Heads, Yamba and Port Macquarie Offshore Tide Gauges 1982–1997,* MHL Report 722, May 1998.

Manly Hydraulics Laboratory 1990, *Batemans Bay Oceanographic and Meteorological Data 1986–1989,* Report No. MHL556.

Manly Hydraulics Laboratory 2010, *Tidal Data Compilation 2010,* MHL Report 1988, June 2010.

Manly Hydraulics Laboratory 2018, *NSW Extreme Ocean Water Levels,* MHL Report 2236, December 2018.

Ocean Tide Program Reports

Manly Hydraulics Laboratory 1987, *Ocean Tide Measurement Program Progress Report,* Report No. MHL471.

Manly Hydraulics Laboratory 1987, *Tide Gauge System: Yamba - Clarence River,* Report No. MHL496.

Manly Hydraulics Laboratory 1990, *NSW Ocean Tide Network Jervis Bay HMAS Creswell Tide Gauge System,* Report No. MHL580.

Manly Hydraulics Laboratory 2005, *Review of Automatic Water Level Recorder Network,* MHL Report 1419, October 2005.

Manly Hydraulics Laboratory 2005, Tide Gauge Histories Metadata for National and NSW Tide Gauges, MHL Report 2179, November 2012.

Manly Hydraulics Laboratory 2013, *North Coast Ocean Tide Scoping Study,* MHL Report 2072, September 2013.

Harmonic Analysis and Tidal Planes

Manly Hydraulics Laboratory 1994, *The Harmonic Analysis of NSW Tide Gauge Network, Volumes 1 and 2,* Report No. MHL604.

Department of Public Works and Services 2003, *DLWC NSW Tidal Planes Data Compilation 2001 – Volume 1 Tidal Plane Analyses*, Manly Hydraulics Laboratory, Report No. 1098.

Department of Public Works and Services 2002, *DLWC NSW Tidal Planes Data Compilation 2001 – Volume 2 Tidal Phase Analyses*, Manly Hydraulics Laboratory, Report No. 1098.

Manly Hydraulics Laboratory 2005, *Investigation into Tidal Planes Compilation – NSW Tidal Planes Data Compilation Stage 3*, MHL Report 1269, November 2005.

Manly Hydraulics Laboratory 2012, *OEH NSW Tidal Planes Analysis: 1990-2010 Harmonic Analysis*, MHL Report 2053, October 2012.

Manly Hydraulics Laboratory 2012, *MHL Tidal Methodology Review,* MHL Report 2156, August 2012.

Manly Hydraulics Laboratory 2014, *OEH NSW Water Level Frequency Distribution Analysis*, MHL Report 2100, March 2014.

Mean Sea Level

Couriel, E, B Modra and R Jacobs 2014, *NSW Sea Level Trends – The Ups and Downs*, 17th Australian Hydrographers Association Conference, Sydney, Australia, October 2014.

Intergovernmental Oceanographic Commission of UNESCO 1985, *Manual on Sea Level Measurement and Interpretation*, IOC Manuals and Guides, No. 14.

Intergovernmental Oceanographic Commission of UNESCO 1986, *Global Sea-level Observing System (GLOSS) Implementation Plan* 1985-1990, IOC/INF-663.

NSW Committee on Tides and Mean Sea Level 1990, The Role of the NSW Committee on Tides and Mean Sea Level.

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