



Public Works
Manly Hydraulics Laboratory

NSW OCEAN AND RIVER ENTRANCE TIDAL LEVELS ANNUAL SUMMARY 2011-2012

Report MHL2158
October 2012



prepared for
Office of Environment and Heritage



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NSW Ocean and River Entrance Tidal Levels Annual Summary 2011-2012

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Rob Jacobs

110b King Street

Manly Vale NSW 2093

T: 02 9949 0200

F: 02 9948 6185

E: rob.jacobs@mhl.nsw.gov.au

W: www.mhl.nsw.gov.au

Cover photograph: Comparison of high tide and storm event 5/6/2012 and calm conditions 8/6/2012 South Curl Curl Pool (Photo courtesy R. Jacobs)

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Foreword

Manly Hydraulics Laboratory (MHL) is a business unit within NSW Public Works, a division of the Department of Finance and Services. The NSW ocean tide database has been developed by MHL to support a number of Department of Premier and Cabinet, Office of Environment and Heritage (OEH) 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 is available to local government and other organisations, both in Australia and overseas.

This annual summary presents ocean and river entrance tidal data captured by the automatic tide level recording stations along the coastline of New South Wales over the period 1 July 2011 to 30 June 2012, and catalogues all ocean and river entrance tidal data collected in NSW by Manly Hydraulics Laboratory.

This summary has been prepared as a guide to enable ready access to MHL's ocean tide database and the data analysis capabilities at the Laboratory.

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.

Requests for further information should be directed to:

Environmental Data Programs	email	:	data-request@mhl.nsw.gov.au
Manly Hydraulics Laboratory	WWW	:	http://www.mhl.nsw.gov.au/
110B King Street	Telephone	:	(02) 9949 0200
MANLY VALE NSW 2093	Facsimile	:	(02) 9948 6185

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Acknowledgement is made of the following contributions to the delivery of the program:

- field management by Phil Clark and Colin Browne
- technical expertise, direction and analysis by Ben Modra.

Summary

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 2011-2012
- the annual data summaries for each site (see [Figure 1](#) for site locations)
- [Appendix A](#) detailing the tidal data available on-line
- [Appendix B](#) detailing the historical tidal data available
- [Appendix C](#) which shows data output formats available from MHL
- [Appendix D](#) glossary of terms
- [Appendix E](#), a list of other publications which may be of interest.

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1. Tidal Network Measurement Program

This report presents the twenty-seventh year of data collected by automatic ocean tide level recorders. The network of recorders and the associated analysis routines enable the Laboratory to provide an efficient service in accessing tide data. In addition to this information, a significant historical database of tide levels can be made available on request.

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 each located on Norfolk Island and Lord Howe Island ([Figure 1](#)). The ocean tide monitoring network features distinctive systems of data capture: radar, electromagnetic tide pole, solid state Floatwell, vented pressure sensor and submersed water level pressure recorder. Each system functions as follows:

- Radar sensors: the water level is detected by RAdio Detection And Ranging technology. The water level is averaged over 60 or 120 seconds to create a 1-minute or 15-minute time series data file respectively. The data recorded is then transferred to MHL via an IP link through a modem between the data logger and MHL's data server. The system is shown in [Figure 2](#).
- Electromagnetic Wave Staff (EWS): the water level is sampled continuously by the EWS. The water level is averaged over 60 or 120 seconds to create a 1-minute or 15-minute time series data file respectively. The data is downloaded every 24 to 48 hours directly from the data logger via an IP link through a modem to MHL's data server or transmitted via radio link to a shore-based receiving station where it can be transferred to MHL via a separate modem connection to the data server. The system is shown in [Figure 3](#).
- 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 then transferred to MHL via an IP link through a modem between the data logger and MHL's data server. The system is shown in [Figure 3](#).
- Solid state Floatwell: the level is sensed by a float connected to a shaft encoder which is read and stored every 15 minutes. The data recorded is then transferred to MHL via an IP link through a modem between the data logger and MHL's data server. The system is shown in [Figure 4](#).
- 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 the Laboratory's data server after recovery from the ocean bed by divers. The system is shown in [Figure 5](#).

Tidal data is transferred to the NSW Data Collection Warehouse, Data Centre 1 at Ultimo and to the Laboratory's data server and is then immediately available to external users to view. 15-minute tide data is available on-line in tables or as plots. One minute data is also available on request (see [Figure C1](#)).

The data is stored in a database and subjected to a quality assurance process which involves several control steps to ensure data quality is maintained. Computer programs are used to further format and analyse data.

The database is backed up daily and data archived to magnetic tape as a security measure at regular intervals. A complete mirrored backup database is also kept at Data Centre 1.

Historical tide chart records converted and available in a digitised format are catalogued in [Appendix A](#). [Appendix B](#) contains the remaining historical database which is retained at the Laboratory in chart form.

2. How to Use This Report

2.1 Using The Data

This annual summary presents ocean and river entrance tidal data captured by the automatic tide level recording stations along the coastline of New South Wales over the period 1 July 2011 to 30 June 2012. The stations are located in bays, harbours and the entrances of major rivers.

To establish if data is available, first identify the relevant station on the Key Map ([Figure 1](#)), then refer to the relevant figure for that station. The map of each station shows its exact location and is followed by the annual plot of data from that station. The plot confirms the availability of data for the fiscal year 2011-2012. For the availability of historical data, which has been collected refer to [Appendices A](#) and [B](#).

Once a selection of data has been made the analysis and/or presentation can be obtained in a variety of formats. The following options are available and samples are shown in [Appendix C](#):

- graphical plots ([Figure C1](#))
- time series data ([Figure C2](#))
- tidal analyses ([Figure C3](#))
- tidal phase difference analysis ([Figure C4](#))
- tidal level ranking ([Figure C5](#))
- tidal predictions ([Figure C6](#)).

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

2.2 Datums

Most ocean tide water levels are recorded in the local port datum which generally equates to Indian Springs Low Water (ISLW). An indicative adjustment of each station datum level to the local Australian Height Datum (AHD) is shown in [Table 2.1](#). These adjustments were calculated circa 1990 for MHL by Roger Harvey from NSW Public Works, using tidal harmonic analysis over a tidal epoch. These values should be used with caution, as AHD levels are revised from time to time and improvements to GPS surveying techniques may provide additional refinement.

Offshore sites are not related to a datum, but are adjusted by harmonic analysis to the Mean Sea Level of each instrument deployment. They provide valuable astronomical constituent and anomaly information. Poor survey information is available for Norfolk Island and Lord Howe Island and ongoing survey works hopes to define offsets to AHD in the coming years.

Table 2.1 Summary of Adjustment to Local AHD

Station	Station Datum	Adjustment (Local to AHD ¹)
Tweed Heads	Tweed River Hydro Datum	0.893
Tweed Heads Offshore	Mean Sea Level	N/A
Brunswick Heads	Brunswick River Flood Mitigation Datum	0.046
Ballina	Low Water Ordinary Spring Tide	0.860
Yamba	Iluka Port Datum	0.895
Yamba Offshore	Mean Sea Level	N/A
Lord Howe Island	Lord Howe Island Hydro Datum	N/A
Norfolk Island	Norfolk Island Tidal Datum	N/A
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
Port Stephens	Port Stephens Hydro Datum	0.944
Patonga	Australian Height Datum	0.000
Sydney	Zero Camp Cove	0.925
Fort Denison	Zero Camp Cove	0.925
Port Hacking	Indian Spring Low Water	0.925
Shoalhaven Offshore	Mean Sea Level	N/A
Crookhaven Heads	Australian Height Datum	0.000
Jervis Bay	Chart Datum	1.070
Ulladulla	Australian Height Datum	0.000
Batemans Bay Offshore	Mean Sea Level	N/A
Princess Jetty	Australian Height Datum	0.000
Bermagui	Bermagui Local Hydro Datum	0.714
Eden Boat Harbour	Twofold bay Hydro Datum	0.924

¹ subtract adjustment from data values to convert to AHD.

2.3 Tidal Planes

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 from this trend. It was also concluded that nearshore sites located at the entrance of large bays/ports or as open ocean sites displayed ranges higher than the closest offshore site, whereas nearshore sites located in river entrances displayed total ranges lower than the closest offshore sites. [Figure 7](#) shows this variation in graphical form. It is important to recognise such variations when applying data from these ocean tide sites.

3. How to Access the Data

The Laboratory 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 on-line in a non-quality controlled form to aid the fastest possible access to data records. The on-line service for clients can provide access to all data catalogued in [Appendix C](#) including tidal predictions. This data consists of tide levels and can be reviewed in graphical or numerical format.

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 upon request.

MHL is currently updating this internet page in association with the updated database and data warehouse capability via Data Centre 1. The new website will include updated functionality, data access and availability of tidal residual plots.

4. Significant Events 2011-2012

Data recovery rates across the NSW Ocean Tide Network in 2011-2012 were very high, with an overall average of 99.6% data collected. The MHL public access web page has proved popular, with 5,152,600 individual internet interactions in 2011-2012.

Data for the offshore tide sites is presented for 2010-2012 for the Tweed Heads (Figures 23, 24, 25), Port Macquarie (Figures 36, 37, 38), Shoalhaven (Figures 51, 52, 53) and Batemans Bay (Figures 60, 61, 62) sites.

The Great Outdoors Publications Pty Ltd will again produce the NSW Tide Prediction Charts for 2013 from data provided by MHL. The charts will be distributed through all NSW coastal newsagencies and are the most complete authoritative charts for coastal NSW (Figure 6). As for the previous tide prediction publications, MHL has adopted the Sydney Harbour Middle Head tide gauge as the primary reference station, and the ocean tide predictions for NSW are based on an analysis of hourly tide levels recorded by this primary gauge. The time difference between the primary and secondary locations in NSW was obtained from an analysis of the tide levels recorded at gauges at each of the secondary locations.

As part of a national project administered by the Intergovernmental Committee on Surveying and Mapping - Geodesy Technical Sub Committee (ICSM-GTSC), MHL co-operated with NSW Land and Property Information (LPI) which undertook a determination of the ellipsoid heights for Ocean Tide stations in 2010-11. Further details are given in the 2010-11 Ocean Tides Annual Summary (MHL Report 2010).

4.1 Tidal Anomalies

Tidal anomalies in this report are calculated as the difference between the recorded data and the Foreman (1977) tidal prediction based on the previous year's (July to June) data. Generally, tidal anomalies are caused by a range of oceanographic and meteorological effects, however for ocean tide gauges located in river entrances hydrological anomalies such as floods can also occur. Further, tsunamis can cause waves that show up on the ocean tide gauges as tidal anomalies.

The anomalies recorded across the NSW coast during the reporting period are shown for a selected group of stations in Figure 8. The major anomalies are identified on Figure 8 and documented in more detail in Figures 9 and 10. Figures 11-14 show the tidal anomalies recorded during the reporting period. Figure 15 shows the anomalies for the four offshore tide stations.

The main drivers of anomalies are barometric pressure, wind set-up and coastally trapped waves and the influence of the East Australian Current (EAC). The NSW Ocean Water Levels report (MHL 2011) investigated anomalies recorded on the NSW coast and considered their occurrence and forcing mechanisms. 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.

Significant anomaly events impacting the NSW coastline are documented in [Figures 9 and 10](#), together with probable causative mechanisms. Most appear to be driven by east coast lows or large high pressure systems.

The Bureau of Meteorology (BoM) recorded two cyclones in North Queensland during the 2011-2012 report period:

- 1-6 February 2012, Cyclone Jasmine Category 2 – moved west to east north of Cairns
- 20–23 December 2011, Cyclone Fina Category 1 – moved north to south as far as Rockhampton.

Neither of these cyclones appeared to have an impact on the tidal anomalies recorded in the Ocean Tide Program. However, other notable events in the anomaly data are:

- 15, 16 July 2011 - large negative anomalies on the south coast particularly at Eden. A large high pressure system dominated the synoptic charts at this time.
- 8 March 2012 - a positive anomaly on top of a high predicted tide resulted in tide heights around or above 2.0 m at Sydney, Port Hacking, Jervis Bay and Coffs Harbour. There was an east coast low centred off Sydney at this time, resulting in heavy rainfall, storms and flooding in the west of NSW.
- Anomalies due to flooding events occur around 23 January 2012 on the north coast (Tweed to Yamba) and 12 June 2012 north coast (Tweed to Yamba).

4.2 Tsunami Events

Table 4.1 lists the tsunami events in the Pacific Region for the period of time corresponding to the 2011-2012 data in this report.

Table 4.1 Tsunami Events July 2011 to June 2012

Date	Cause		Location	Observable on NSW Tide Recordings
	Earthquake Magnitude (M_w)	Other Causes		
6/7/2011	7.6	-	Kermadec Islands, NZ	No
20/8/2011	7.1	-	Vanuatu Islands	No
21/10/2011	7.4	-	Kermadec Islands, NZ	No
2/2/2011	7.0	-	Vanuatu Islands	No
14/3/2012	6.9		Hokkaido Islands, Japan	No

Date	Cause		Location	Observable on NSW Tide Recordings
	Earthquake Magnitude (M _w)	Other Causes		
11/4/2012	8.6	-	West Coast N Sumatra, Indonesia	No
14/4/2012	6.3	-	Vanuatu Islands	No

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

The Bureau of Meteorology and Geoscience Australia host the Joint Australian Tsunami Warning Centre (JATWC). No tsunami warnings were issued by JATWC from July 2011 to June 2012. The Bureau of Meteorology collects specific tsunami data for issuing warnings, and the data can be requested from BoM for further use.

4.3 Brunswick Heads Phase Anomaly September 2011

Observations of data at Brunswick Heads indicate positive anomalies coinciding with ocean storm events that show a phase shift on the outgoing tide compared with the predicted tide.

An example on 27 September 2011 shows a large positive anomaly at Brunswick Heads coinciding with an ocean storm event but no rainfall (significant wave height of 4.4 m at Byron Bay Waverider buoy). In this event, the outflow of the tide is seen to get out of phase with the predicted tide, producing an out-of-phase anomaly. It would appear that the anomaly may be related to offshore wave conditions and the degree of the accretion and outflow resistance of the entrance bar. This event can also be seen at the Tweed and Ballina breakwall sites to a lesser degree. [Figure 16](#) shows a plot of this event.

4.4 Vessel Grounding, Lord Howe Island October 2011

The MV Island Trader regularly supplies Lord Howe Island with cargo. It operates from Port Macquarie to Lord Howe Island. On Monday 17 October 2011 following unloading of cargo on Lord Howe Island the MV Island Trader was forced aground on a sand bank due to high winds.

MHL assisted the Pilot and the Lord Howe Island Board in their attempts to refloat the vessel by providing a real time data link via an internet webpage. After an unsuccessful attempt to refloat on 23 October the vessel was successfully refloated on the high tide on 24 October. A plot of the tides during this period is shown in [Figure 17](#). Following the event, the CEO of the Lord Howe Island board expressed thanks to MHL for assistance in the planning of the refloating of the vessel.

4.5 Coastal Trapped Wave April 2012

During April 2012 the CSIRO observed a Coastal Trapped Wave (or Rossby Wave) through the Integrated Marine Observing System (IMOS). The following description of the event comes from Dr David Griffin of CSIRO from the IMOS website (<http://imos.org.au>).

'A wave of high sea level propagated northwards along the entire east Australian coast from Bass Strait on 8 April through NSW on 10 April, SE Qld on 13 April to Cape York on 15 April. It was the result of winds associated with a high pressure system that developed in the Great Australian Bight farther south than normal for April, at a latitude more typical for summer-time systems. Unlike a summer system, however, it then tracked onto the SE mainland and up towards Qld. The result was that strong westerly winds off Vic preceded strong southerlies off NSW and strong south-easterlies off Qld. There is a class of low-frequency (period of days or longer), large-scale (100's km wavelength) ocean wave known as a Topographic Rossby wave, or Coastal Trapped Wave that propagates along continental shelves with the coast on the left in the southern hemisphere (i.e. northwards on the east coast) at a few hundred km per day depending on the depth profile of the shelf. They are generated by the along-shore component of the wind and reach largest amplitudes when the translocation of the strong winds matches the speed of the wave. This recent event appears to be a classic example of the local response to the wind being compounded by a Coastal Trapped Wave. The result was that sea level was about 0.5m higher than expected for a day or two in places, something that only happens once or twice, if at all, each year. A northward shift of the prevailing current, of possibly 0.5m/s for a day or two, might have also occurred over the continental shelf but this is yet to be confirmed. Downwelling of the thermocline over the continental slope may also have occurred, especially near topographic irregularities such as Fraser Island.'

Figure 18 shows a plot of the anomaly at four ocean tide sites during this period, which indicates the wave moving northward along the coast.

4.6 High Tide Event June 2012

In June 2012 a high tide and an east coast low coincided on the NSW coast. The coincidence occurred on 5 and 6 June 2012 and produced a positive anomaly along the coast. Tide heights above 2.0 m were recorded along the NSW coast. During this period high water levels and surges, together with overtopping of coastal structures and damage, were reported along the coast. Figures 19 and 20 show some photos of the event.

4.7 Lord Howe Island Yearly Anomalies

Observation of the tidal predictions at Lord Howe Island have shown large variations in the residuals. High magnitudes and long periods of oscillations at these high magnitudes are evident when using the traditional July to June yearly forecast from the previous year of data.

An Astronomical Forecast (forecast created from the same period of time as the measured data) was created for July 2010 to June 2011 and compared to residual from previous years' measured data. The maximum and minimum absolute values of the residuals were less, but the trends are similar but not always the same.

Lord Howe does not have a full epoch (18.6 years) of data so following discussions with Mike Foreman, MHL combined the cosine and sine terms of individual years tidal constituents analysis to produce a harmonic constituent file representing an average of 15 years of data.

From this harmonic file a forecast was produced and the residuals compared to the residuals produced in the previous step. The long residual followed similar trends but still showed residuals of high magnitude with long periods of significant anomaly.

A review of the constituent values for the site over the years of record showed that the diurnal and semi-diurnal constituents are very consistent over the record. However, the longer constituents at a year and half-year (SA and SSA) change dramatically over the record. The cause of this is not yet known but could be associated with oceanic processes that operate at a similar time scale.

Therefore, forecasts using the previous year's record will not produce accurate predictions for the following year. Two methods of addressing the issue are apparent, but need to be more fully investigated:

- use the same year of data as the prediction (obviously for historical records not forecasts)
- use the average of the constituents over a long period (the value shown as a red circle in the plots below)

Further observations indicate that the East Australia Current eddies may have an influence on the anomalies at Lord Howe, and further investigation is required.

4.8 Publications

The following MHL reports currently in preparation contain information and analyses relating to the Ocean Tide program:

- North Coast Ocean Tide Site Scoping Study, MHL Report 2072
- OEH NSW Tidal Planes Analysis 1990–2010 Harmonic Analysis, MHL Report 2053
- Coincidence of Catchment and Coastal Flooding: Phase 1, MHL Report 2075
- NSW Water Level Frequency Distribution Analysis, MHL Report 2100
- MHL Tidal Methodology Review, MHL Report 2156.

5. Program Developments 2011-2012

5.1 Classification of Sites

An increasing interest in sea level rise, tsunami and storm surge data has led to the adoption of a classification of each of the sites 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 of the data possible variability of data based on recording location.

The four classifications are:

- Onshore River Entrance – sites that are located within a river a short distance upstream of the entrance usually maintained open by training walls. Good representation of ocean water levels, but 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 influence by floods. Can be influenced by harbour motions.
- 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
- 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 datum cannot be accurately determined.

The classification indicates sites that are similar in their location and gives an indication to the end user of the data of the site location type that would be most representative for the required analysis for a specific project. Table 5.1 lists the classification of each of the sites in the program.

Table 5.1 Ocean and River Entrance Tide Site Classification

Station	Classification	Classification Code
Tweed Heads	Onshore River Entrance	OR
Tweed Heads	Offshore Open Ocean	O
Brunswick Heads	Onshore River Entrance	OR
Ballina Breakwall	Onshore River Entrance	OR
Yamba	Onshore River Entrance	OR
Norfolk Island	Onshore Open Ocean	OO
Lord Howe Island	Onshore Open Ocean	OO

Station	Classification	Classification Code
Coffs Harbour	Onshore Bay or Port	OB
Port Macquarie	Onshore River Entrance	OR
Port Macquarie	Offshore Open Ocean	O
Crowdy Head	Onshore Bay or Port	OB
Forster	Onshore River Entrance	OR
Port Stephens	Onshore Bay or Port	OB
Patonga	Onshore River Entrance	OR
Sydney	Onshore Bay or Port	OB
Port Hacking	Onshore Bay or Port	OB
Shoalhaven	Offshore Open Ocean	O
Crookhaven	Onshore River Entrance	OR
Jervis Bay	Onshore Bay or Port	OB
Ulladulla	Onshore Bay or Port	OB
Princess Jetty	Onshore River Entrance	OR
Batemans Bay	Offshore Open Ocean	O
Bermagui	Onshore River Entrance	OR
Eden	Onshore Bay or Port	OB

5.2 Program Improvements / Changes

Further improvements and changes to the network have continued in 2011-2012. [Table 5.2](#) shows the status of the sites as of June 2011. The following summarises the major changes:

- Patonga and Princess Jetty sites incorporated into the program and upgraded to 1-minute data and dual sensors.
- Sydney and Lord Howe Island primary sensors upgraded to a radar sensor.
- Lord Howe Island primary sensor upgraded to record at 1-second intervals to onsite data storage card (see example data in [Figure C1](#)).
- EWS or Floatwell sensors decommissioned and replaced with vented pressure sensors at Bermagui and Coffs Harbour.
- Sydney site re-established with radar sensor and backup site retained as a duplicate site with separate sensors, logger and communications.
- New RBR instrumentation enabled 5-minute logging at offshore sites from mid-2012.
- New public website for MHL and WISKI database operational.

Table 5.2 MHL Tidal Logging and Sensing System Status June 2011

Station	Site Classification ¹	Primary Loggers	Secondary Loggers	Primary Sensors	Secondary Sensors	Station	
						Sampling	Logging
Tweed Heads	OR	CR800		Vented Pressure	Vented Pressure	120 samples averaged 1 minute either side of the quarter hour and 60 samples averaged 30 seconds either side of each minute	15 minutes on the quarter hour and 1 minute on the minute
Brunswick Heads	OR	CR800	-	Vented Pressure	Vented Pressure		
Ballina Breakwall	OR	CR800	-	Vented Pressure	Vented Pressure		
Yamba	OR	CR800	-	Vented Pressure	Vented Pressure		
Coffs Harbour	OB	CR800		Vented Pressure	Vented Pressure		
Port Macquarie	OR	CR800	-	Vented Pressure	Vented Pressure		
Crowdy Head ³	OB	CR800	-	Vented Pressure	Vented Pressure		
Forster	OR	CR800	-	Vented Pressure	Vented Pressure		
Port Stephens	OB	CR800	-	Radar	Vented Pressure		
Patonga	OR	CR800		Floatwell	Vented Pressure		
Sydney	OB	CR800		Radar	n/a		
Sydney Backup	OB	CR800		Vented Pressure	Vented Pressure		
Port Hacking	OB	CR800	MetOcean	Electromagnetic	Vented Pressure		
Crookhaven	OR	CR800	-	Vented Pressure	Vented Pressure		
Jervis Bay	OB	CR800	-	Radar	Vented Pressure		
Ulladulla	OB	CR800	-	Vented Pressure	Vented Pressure		
Princess Jetty	OR	CR800		Vented Pressure	n/a		
Bermagui	OR	CR800	-	Vented Pressure	Vented Pressure		
Eden	OB	CR800n		Radar	Vented Pressure		
Norfolk Island	OO	CR800	-	Floatwell	Vented Pressure		
Lord Howe Island	OO	CR1000	-	Radar	Vented Pressure		
Tweed Heads ²	O	WLR7	-	Submersible Paroscientific Pressure Sensor and RBR Logger	Aanderaa Submersible Pressure	Integrated over 40 seconds	RBR 5 minutes Aanderaa 60 minutes
Port Macquarie ²	O	WLR7	-				
Shoalhaven ²	O	WLR7	-				
Batemans Bay ²	O	WLR7	-				

¹ Classification: O = Offshore Open Ocean, OO = Onshore Open Ocean, OR = Onshore River entrance, OB = Onshore Bay or Port

² Offshore tidal site

5.3 Program Plans 2011-2012

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 2011-2012 program upgrades include:

- continued rollout of radar sensors to be progressively installed at Tweed Heads, Coffs Harbour, Port Macquarie, Crowdy Head, Patonga and Princess Jetty
- automated status reports from the field to the database
- high frequency logging (1 second) upgrades at Port Stephens, Sydney, Jervis Bay and Eden.

6. Index of Figures

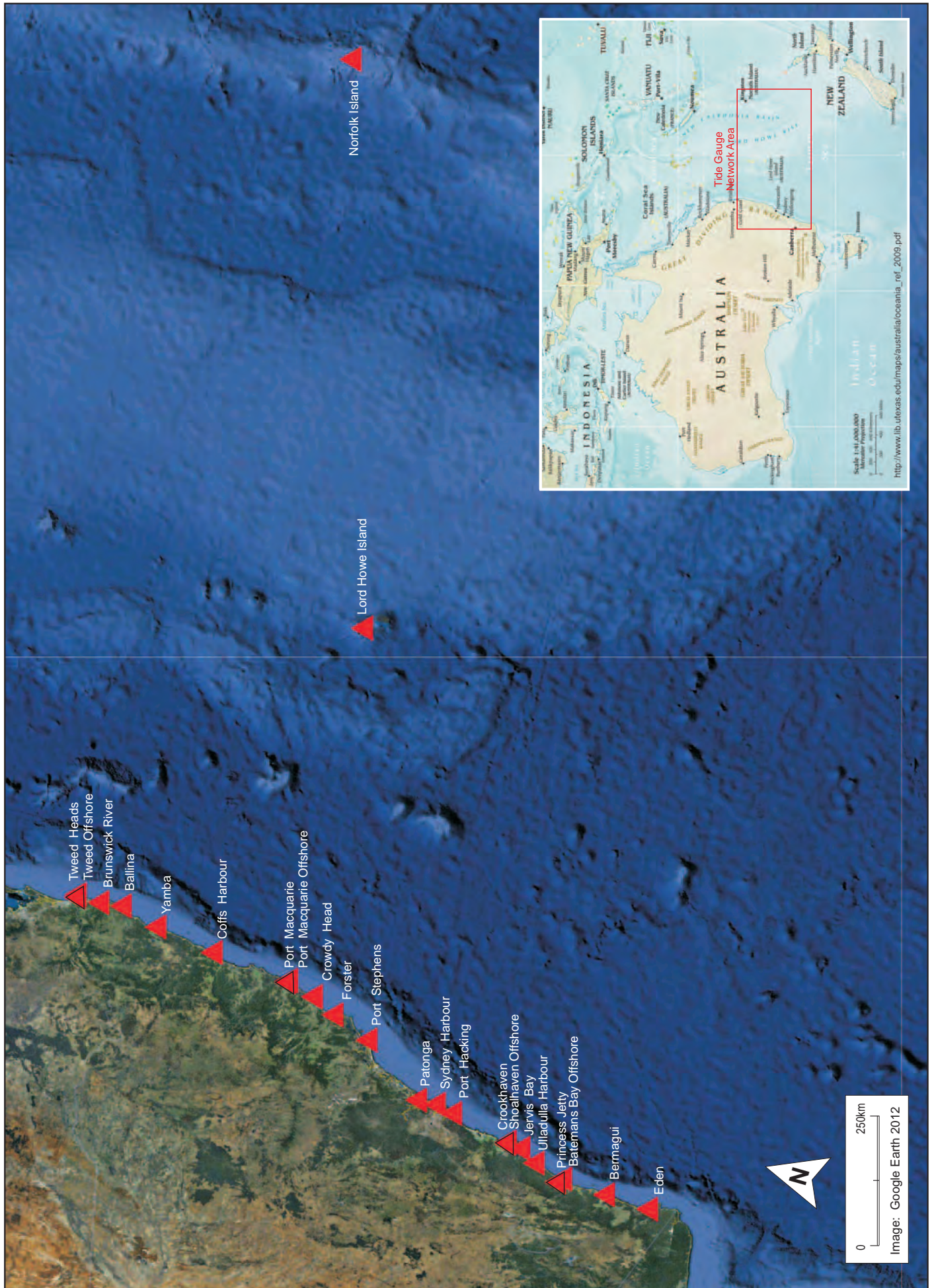
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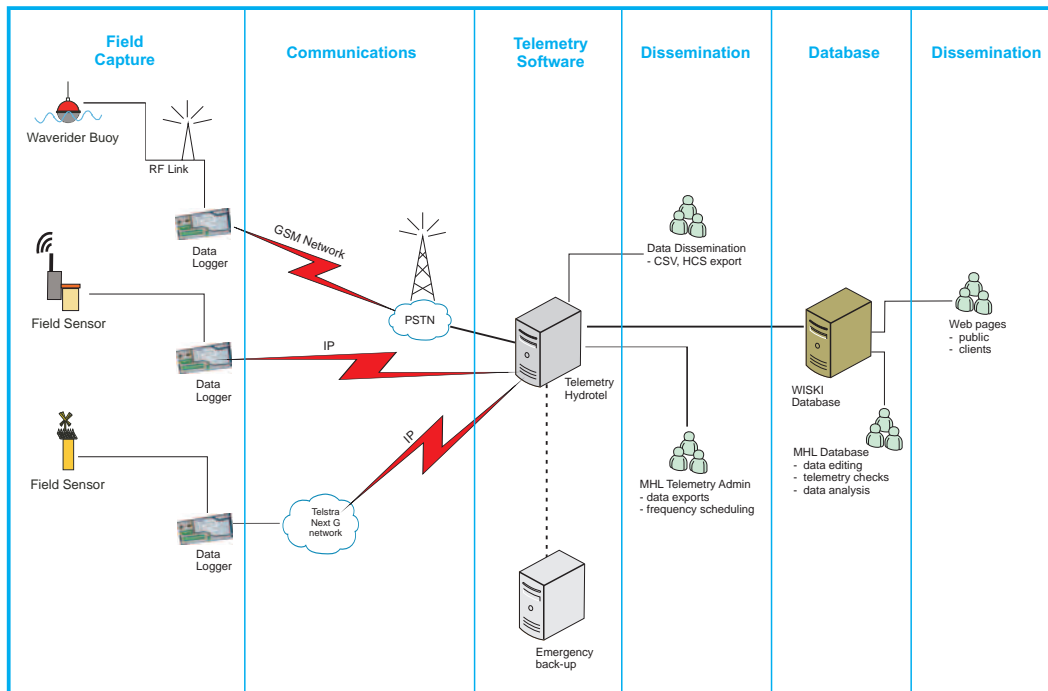
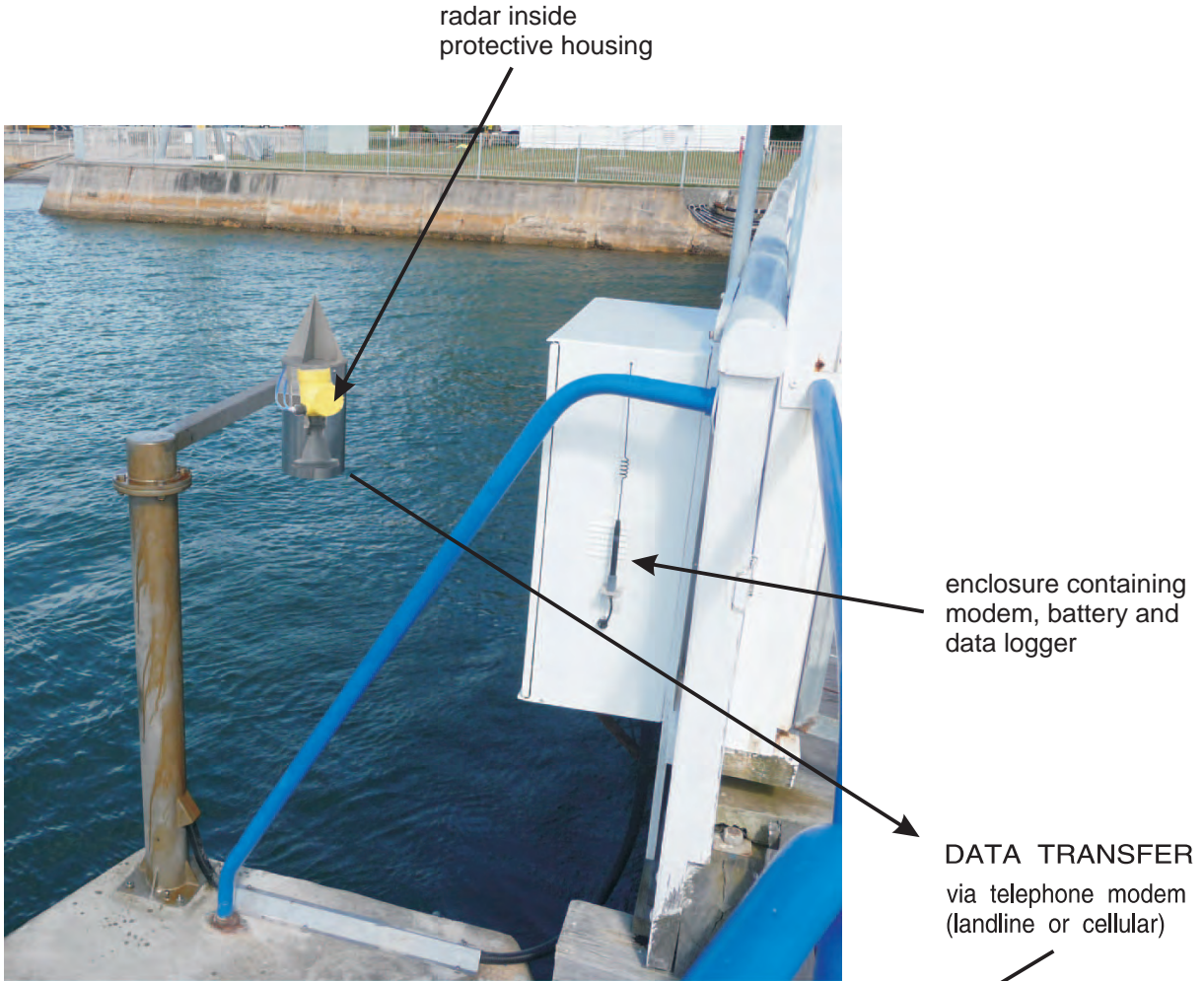
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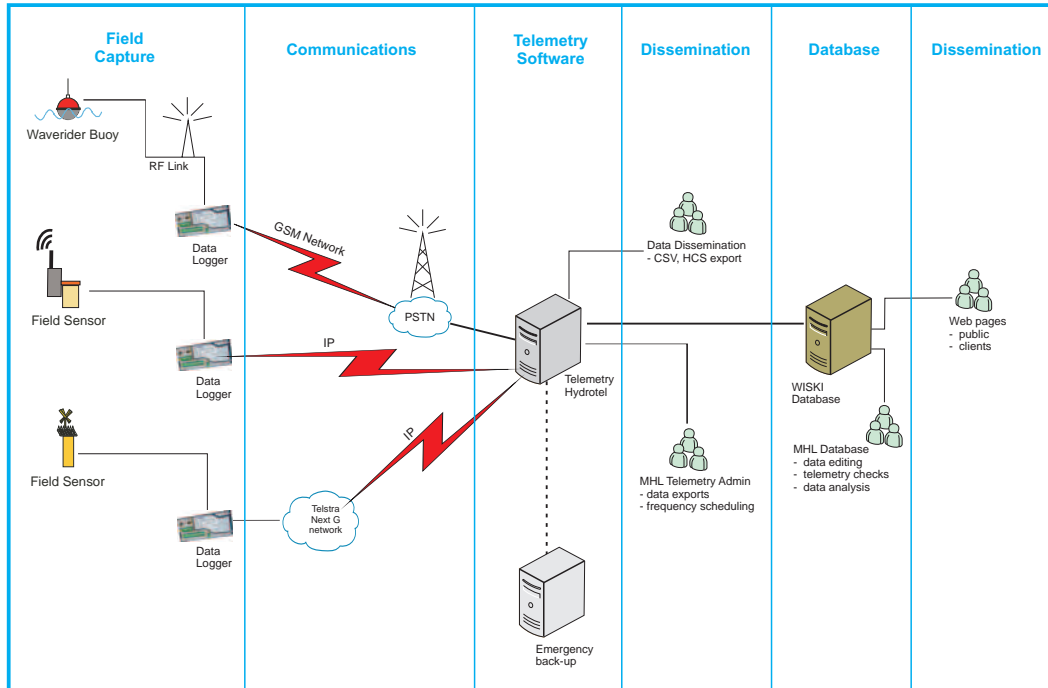
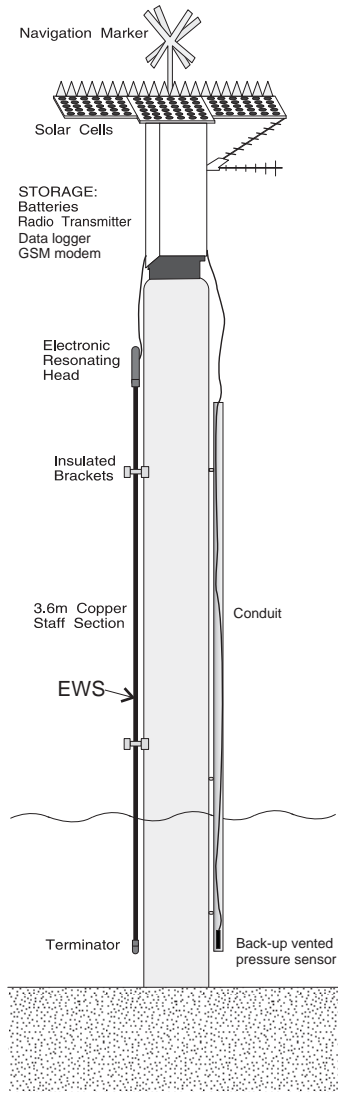
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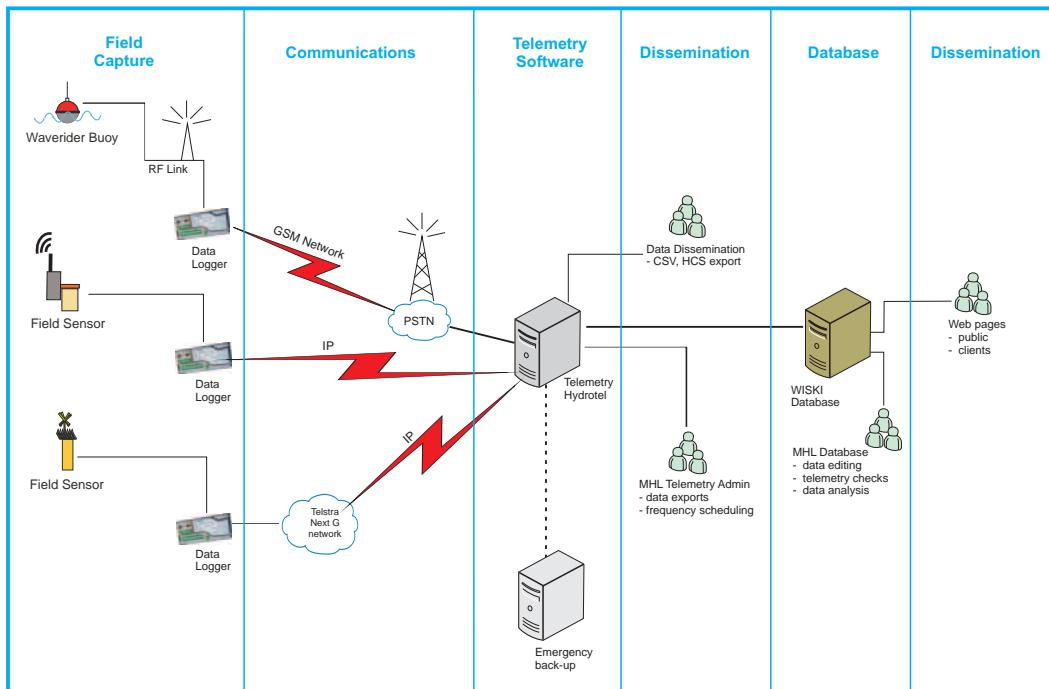
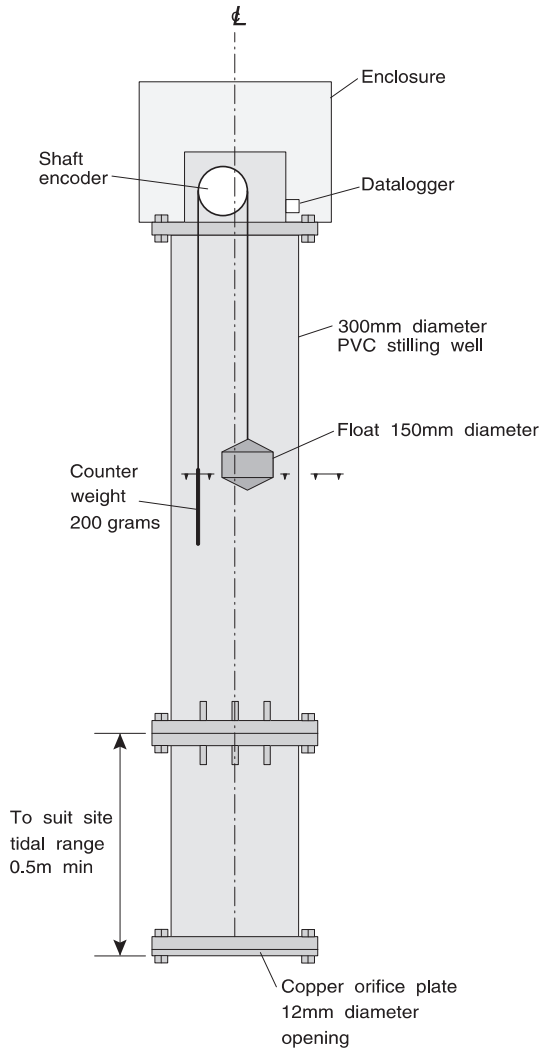
7. References

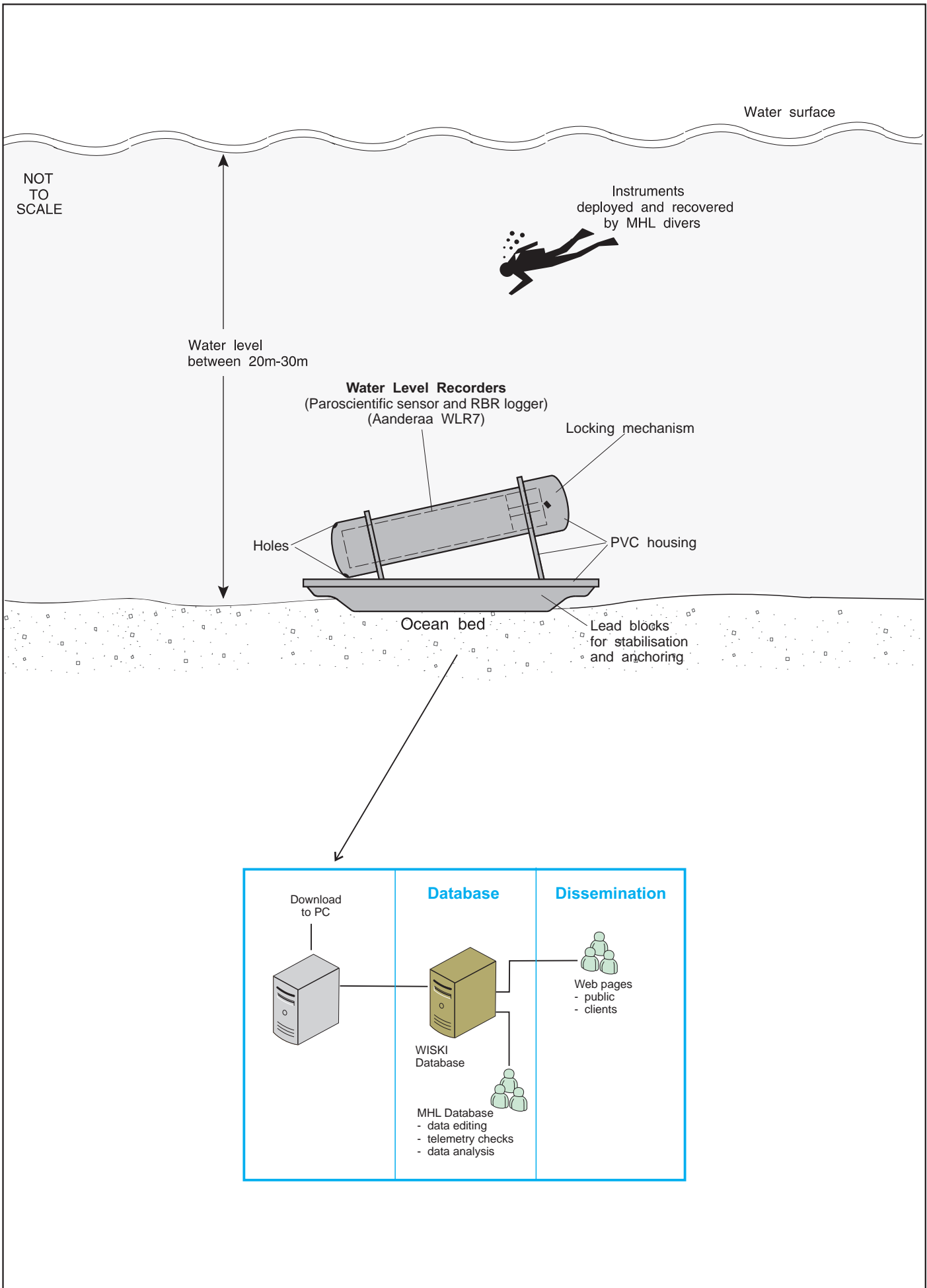
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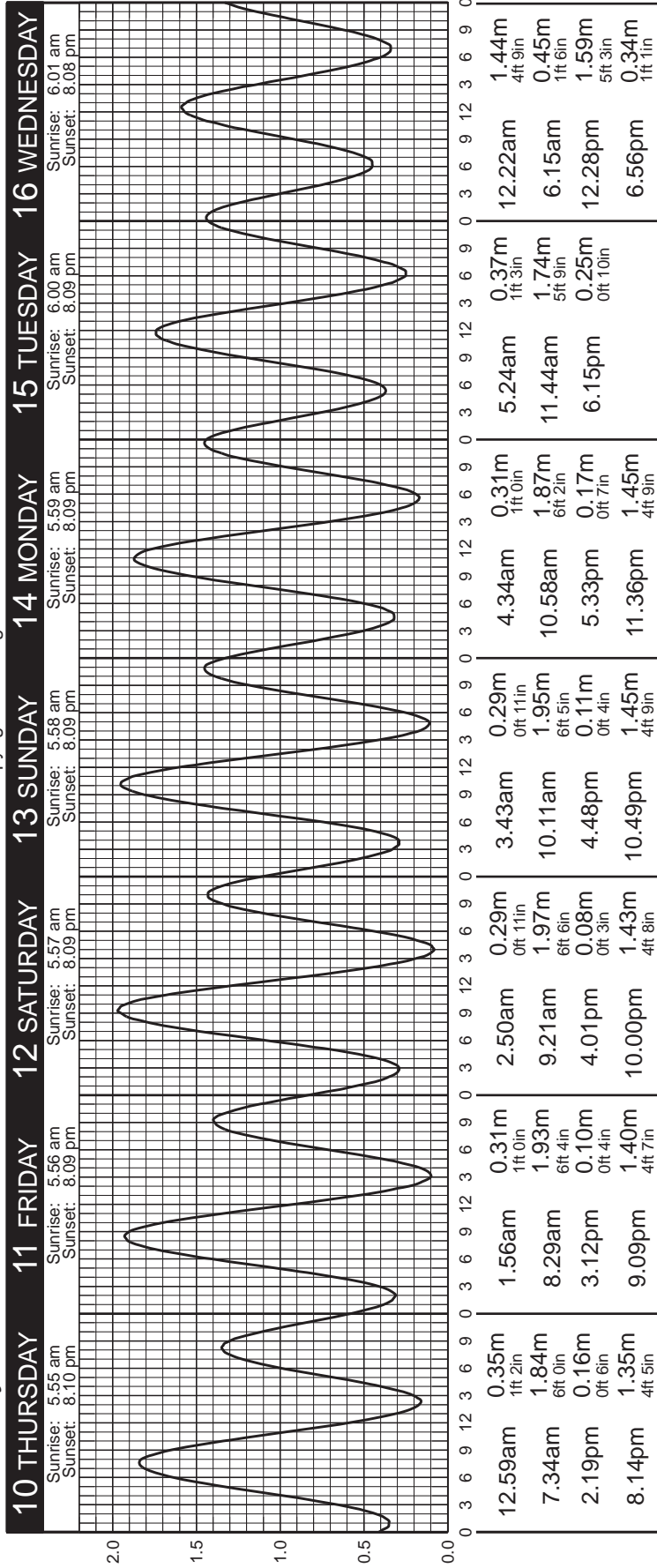




January 10-16, 2013

Daylight Savings Time
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● New Moon Jan 12



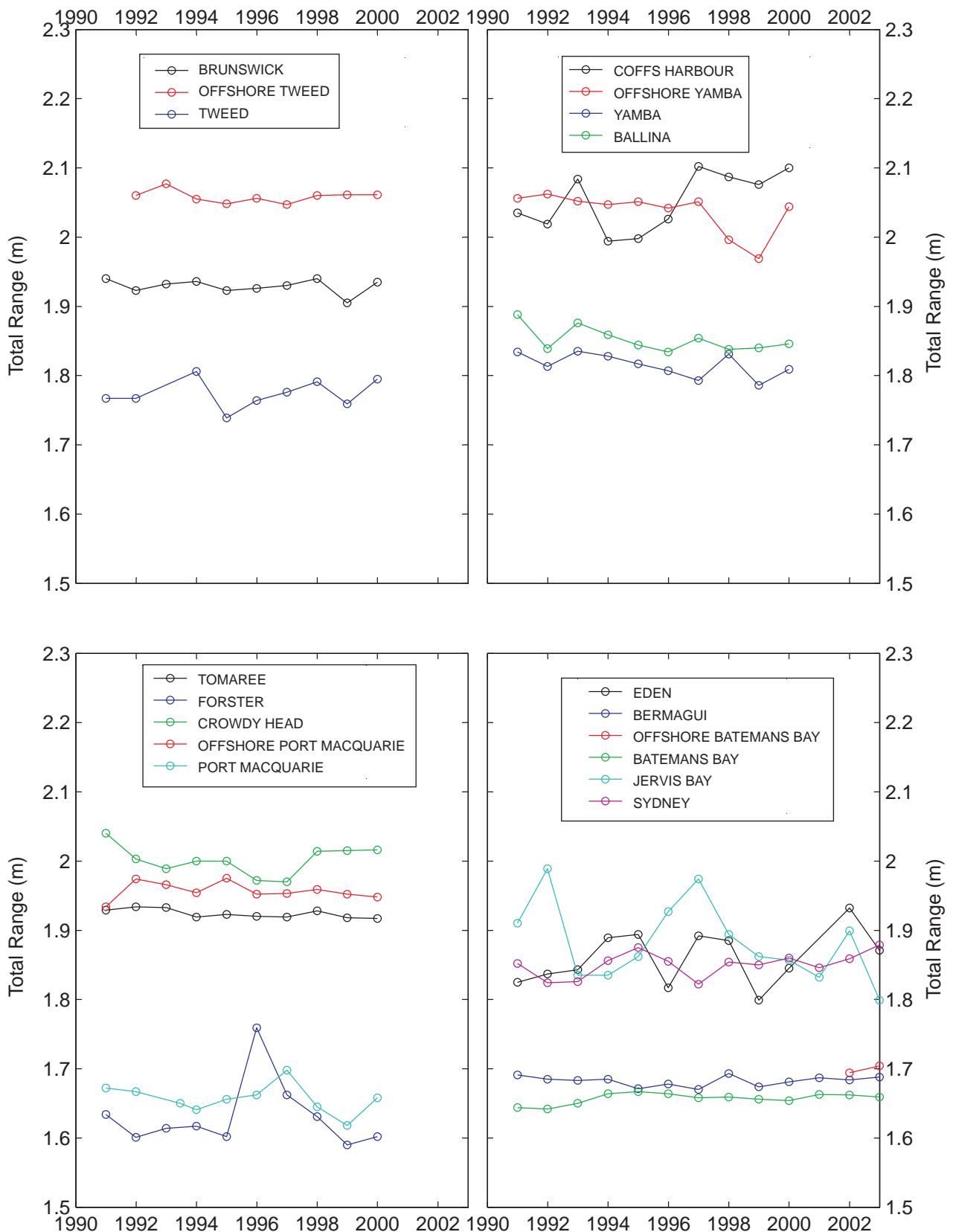
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NSW TIDAL PREDICTIONS
Extract from 'NSW TIDE CHARTS 2013'

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Figure
6

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

Source: MHL1269 2005



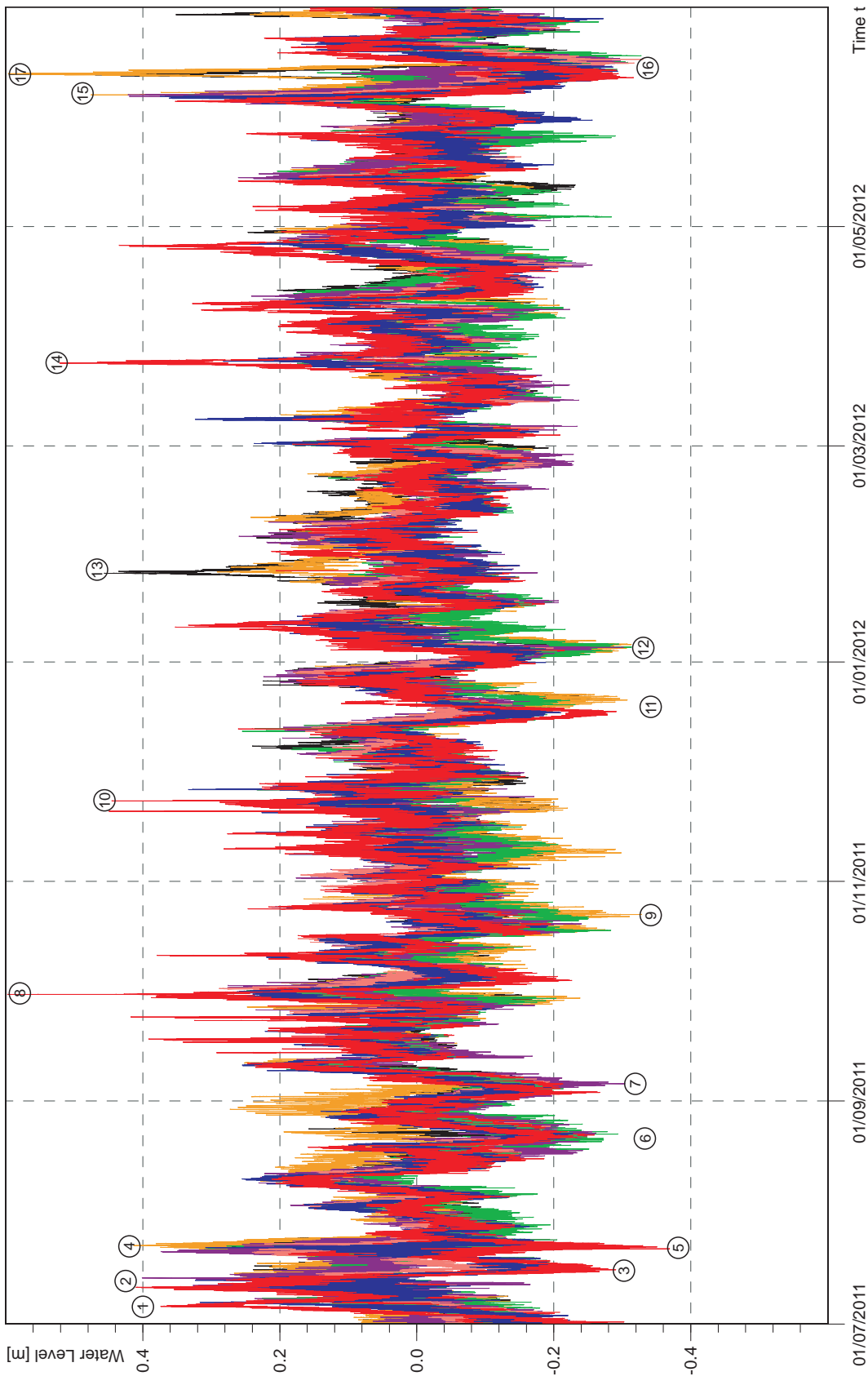
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**TIDAL RANGE FOR GROUPED OFFSHORE
AND NEARSHORE GAUGES
1990-2003**

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Report 2158

Figure
7

DRAWING 2158-07.cdr



Event	Tidal Anomaly	Tweed	Brunswick	Ballina Breakwall	Yamba	Coffs Harbour	Port Macquarie	Crowdy Head	Forster	Port Stephens	Patonga	Sydney	Port Hacking	Crookhaven	Jervis Bay	Ulladulla Harbour	Princess Jetty	Bermagui	Eden	
1 6-8 July 2011 Low pressure south of Tasmania, westerly stream through Bass Strait	Peak (m) Date Time							0.24 8/7 1:15			0.23 7-Jul 3:45			0.22 6/7 19:45	0.26 6/7 20:30	0.32 6/7 23:15	0.29 6/7 20:30	0.30 6/7 16:45	0.37 6/7 20:45	
2 11-13 July 2011 Continuation of westerly stream in Bass Strait	Peak (m) Date Time	0.26 15/7 01:45	0.21 15/7 00:15	0.27 15/7 03:00	0.24 14/7 12:30	0.24 14/7 02:00	0.28 13/7 19:15	0.40 13/7 18:30	0.24 11/7 09:00	0.19 13/7 06:15	0.22 12/7 18:30					0.32 13/7 03:15	0.29 11/7 17:45	0.30 11/7 07:30	0.41 11/7 04:45	
3 15-16 July 2011 Large high dominating Tasman Sea	Peak (m) Date Time										-0.23 16/7 13:15	-0.21 16/7 04:15	-0.28 15/7 23:30	-0.20 15/7 23:00	-0.25 16/7 10:30	-0.25 15/7 20:45	-0.29 16/7 04:00	-0.26 15/7 19:30	-0.29 16/7 02:15	
4 20-22 July 2011 East Coast Low	Peak (m) Date Time	0.33 22/7 19:30	0.37 22/7 18:15	0.41 22/7 19:15	0.29 22/7 07:45	0.31 21/7 15:30	0.32 22/7 05:30	0.37 21/7 02:30	0.28 21/7 04:15	0.24 20/7 22:30						0.31 22/7 05:30				
5 21-24 July 2011 High pressure following East Coast Low	Peak (m) Date Time																			
6 16-25 August 2011 Large high dominating Tasman Sea	Peak (m) Date Time	-0.18 21/8 23:15	-0.25 21/8 12:15	-0.17 20/8 01:00	-0.22 19/8 23:15	-0.29 22/8 19:00	-0.19 20/8 07:45	-0.26 23/8 01:15	-0.25 22/8 11:00	-0.22 23/8 11:00	-0.27 22/8 00:00	-0.26 22/8 13:15	-0.29 22/8 04:15	-0.21 22/8 02:00	-0.25 21/8 22:15	-0.23 22/8 21:45	-0.27 22/8 09:45	-0.21 22/8 10:15	-0.23 21/8 20:15	
7 3-5 September 2011 Large high dominating Tasman Sea	Peak (m) Date Time							-0.30 5/9 19:00	-0.26 5/9 15:15	-0.20 5/9 14:30	-0.22 4/9 23:00	-0.21 5/9 16:15	-0.24 5/9 15:00	-0.18 5/9 11:45	-0.21 4/9 10:00	-0.20 4/9 16:30	-0.26 4/9 01:45	-0.18 3/9 12:15	-0.27 3/9 08:45	
8 27 Sept-3 October 2011 East Coast Low	Peak (m) Date Time	0.22 27/9 00:45	0.45 27/9 12:00	0.25 27/9 01:30	0.18 3/10 19:15	0.23 1/10 16:15	0.22 2/10 21:00	0.28 2/10 11:15	0.25 2/10 16:00	0.29 2/10 05:45	0.20 1/10 19:30	0.23 2/10 03:00	0.23 1/10 17:30	0.25 1/10 15:00	0.27 1/10 02:45	0.30 1/10 06:00	0.22 1/10 05:15	0.35 29/9 13:30	0.60 30/9 14:45	

The tidal anomalies were calculated by comparing the actual recorded water level with the predicted water level.
The predicted data was generated using harmonic constituents from the previous year.
The anomalies in this table are based on a ranking of 15-minute data.

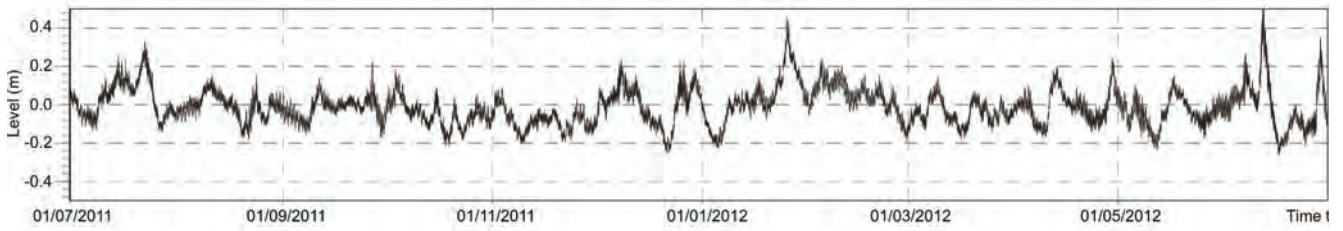


Event	Tidal Anomaly	Tweed	Brunswick	Ballina Breakwall	Yamba	Coffs Harbour	Port Macquarie	Crowdy Head	Forster	Port Stephens	Patonga	Sydney	Port Hacking	Crookhaven	Jervis Bay	Ulladulla Harbour	Princess Jetty	Bermagui	Eden	
9 18-24 October 2011 Large high dominating Tasman Sea	Peak (m) Date Time	-0.22 19/10 08:45	-0.22 18/10 10:15	-0.33 22/10 19:00	-0.26 22/10 22:45	-0.28 22/10 09:15	-0.24 18/10 22:30	-0.24 23/10 05:15	-0.17 20/10 10:45	-0.15 20/10 10:15	0.2 26/11 15:45	-0.20 20/10 04:15	0.26 26/11 15:45	0.26 26/11 15:30	0.23 26/11 11:15	0.33 26/11 12:00	0.25 27/11 04:30	0.26 22/11 10:45	-0.30 13/1 04:30	
10 22-26 November 2011 Low trough	Peak (m) Date Time						0.24 26/11 06:30			0.20 23/11 07:15	0.2 26/11 15:45	0.20 26/11 23:00	0.26 26/11 15:45	0.26 26/11 15:30	0.23 26/11 11:15	0.33 26/11 12:00	0.25 27/11 04:30	0.26 22/11 10:45	0.45 23/11 09:00	
11 17-22 December 2011 Complex pattern of lows and highs with TC Fina	Peak (m) Date Time	-0.26 21/12 20:00	-0.23 22/12 05:15	-0.31 21/12 08:45	-0.34 21/12 21:15	-0.23 20/12 02:45	-0.23 20/12 17:45								-0.21 18/12 00:45	-0.21 17/12 21:30	-0.25 17/12 14:45	-0.25 17/12 19:15	-0.29 18/12 05:15	
12 3-5 January 2012 Large high dominating Tasman Sea	Peak (m) Date Time	-0.23 5/1 15:00	-0.21 5/1 07:15	-0.31 5/1 20:30	-0.39 4/1 20:30	-0.31 5/1 02:00	-0.32 4/1 19:45	-0.30 5/1 00:45	-0.20 4/1 22:00	-0.20 4/1 20:15	-0.23 3/1 15:30	-0.21 4/1 04:15	-0.20 3/1 22:15	-0.20 4/1 21:00	-0.20 3/1 22:00					
13 23-26 January 2012 Low trough, flooding	Peak (m) Date Time	0.46 25/1 15:15	0.79 25/1 15:30	0.29 26/1 01:00	0.36 27/1 08:45	0.12 23/1 04:30	0.23 26/1 16:45													
14 23-24 March 2012 Low trough	Peak (m) Date Time										0.22 23/3 14:00				0.21 24/3 15:30	0.28 24/3 13:45	0.30 24/3 21:30	0.38 24/3 11:15	0.52 24/3 01:30	
15 5-7 June 2012 Series of East Coast Lows, flooding	Peak (m) Date Time	0.26 7/6 01:15	0.31 7/6 03:30	0.48 6/6 14:15	0.34 6/6 13:45	0.37 6/6 12:30	0.51 6/6 13:00	0.42 6/6 14:00	0.30 6/6 03:30	0.31 6/6 00:45	0.54 6/6 03:15	0.28 6/6 00:00	0.15 5/6 20:15	0.22 6/6 04:30	0.28 5/6 18:30	0.37 6/6 02:15	0.45 5/6 15:15	0.26 5/6 13:45	0.35 4/6 18:45	
16 11-16 June 2012 High pressure system	Peak (m) Date Time	-0.26 16/6 22:00	-0.23 18/6 11:15	-0.24 16/6 22:00	-0.27 16/6 18:30	-0.33 17/6 10:45	-0.22 17/6 02:30	-0.31 15/6 13:00	-0.29 15/6 11:15	-0.33 16/6 11:00	-0.22 13/6 16:15	-0.24 10/6 23:00	-0.32 14/6 04:00	-0.25 13/6 17:45	-0.29 13/6 15:15	-0.29 13/6 02:30	-0.23 13/6 04:15	-0.33 13/6 01:00	-0.32 11/6 08:15	
17 12-22 June 2012 East Coast Lows around 12 and 22 June, flooding	Peak (m) Date Time	0.60 12/6 07:45	0.62 12/6 07:45	0.60 12/6 10:45	0.29 12/6 10:00	0.16 12/6 16:45	0.29 12/6 10:00									0.21 22/6 06:30	0.20 18/6 14:15	0.20 18/6 14:15	0.20 18/6 06:45	

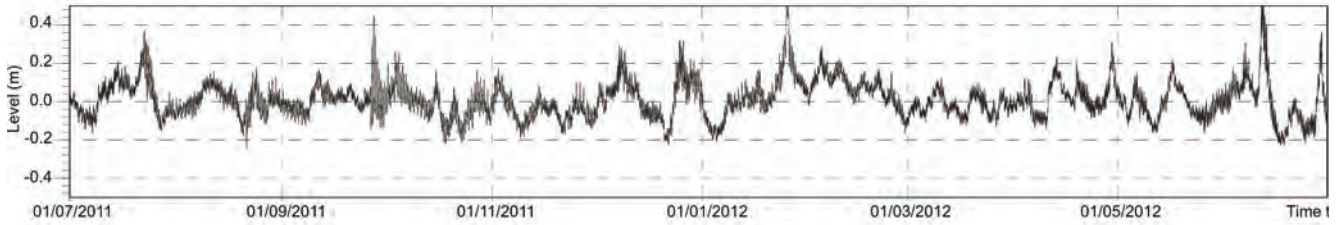
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The predicted data was generated using harmonic constituents from the previous year.
The anomalies in this table are based on a ranking of 15-minute data.



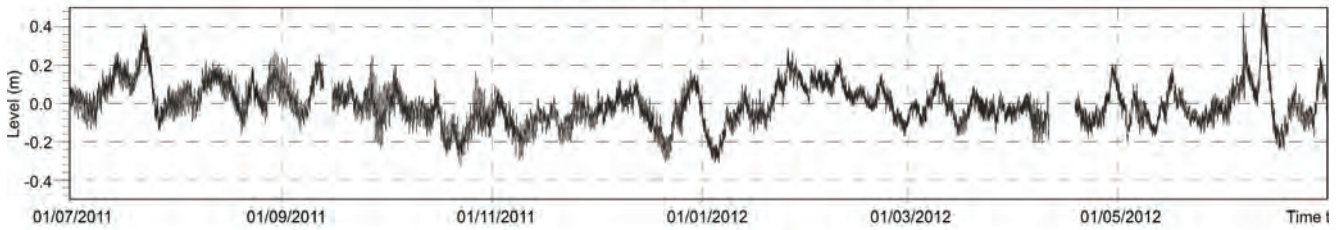
Tweed River at Tweed Heads



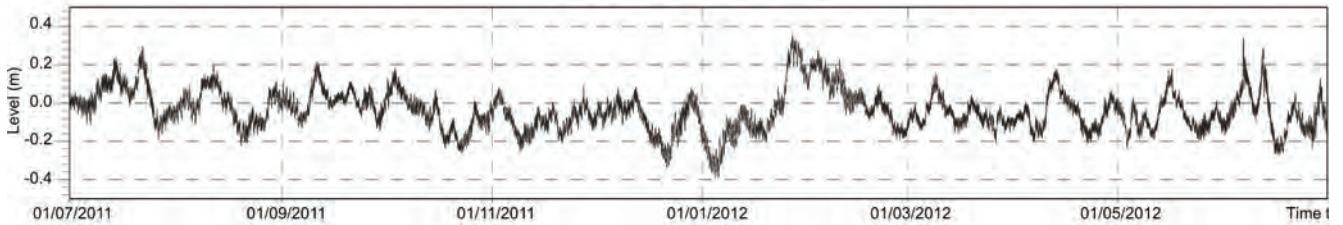
Brunswick River at Brunswick Heads



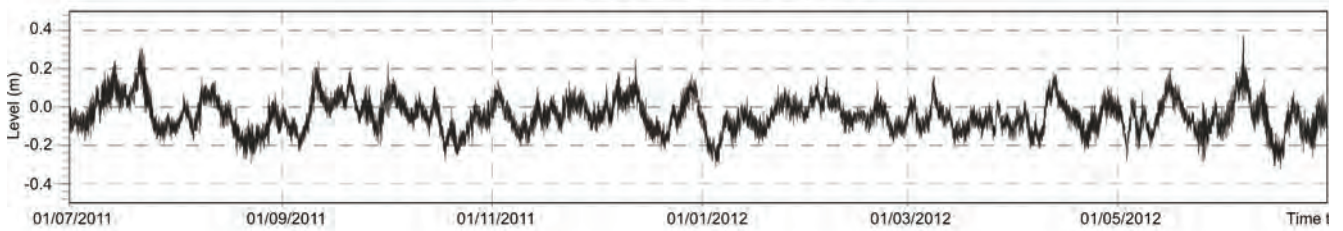
Richmond River at Ballina Breakwall



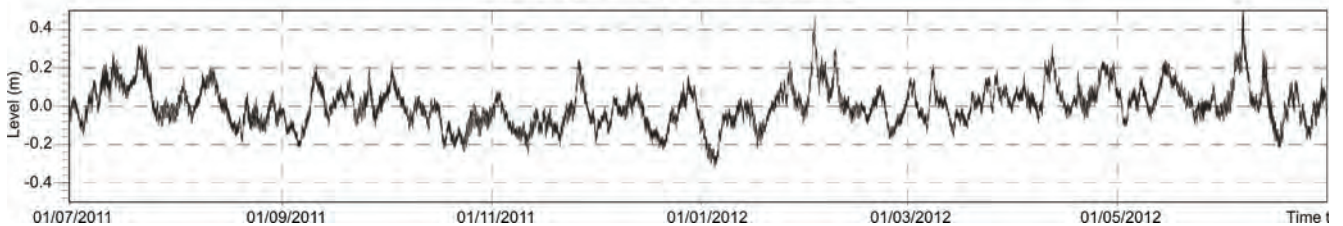
Clarence River at Yamba



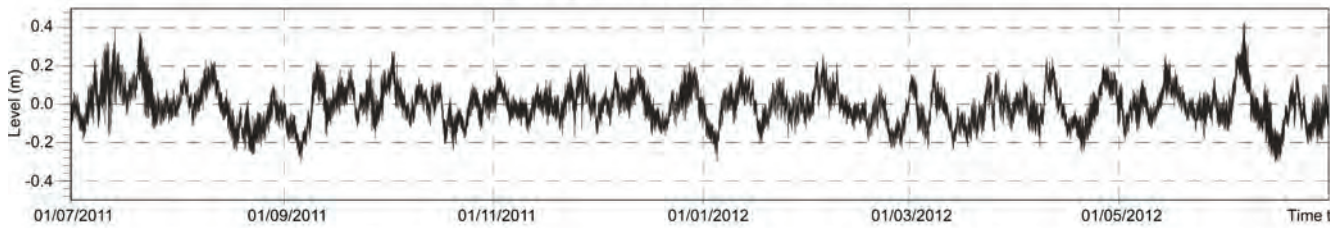
Tasman Sea at Coffs Harbour



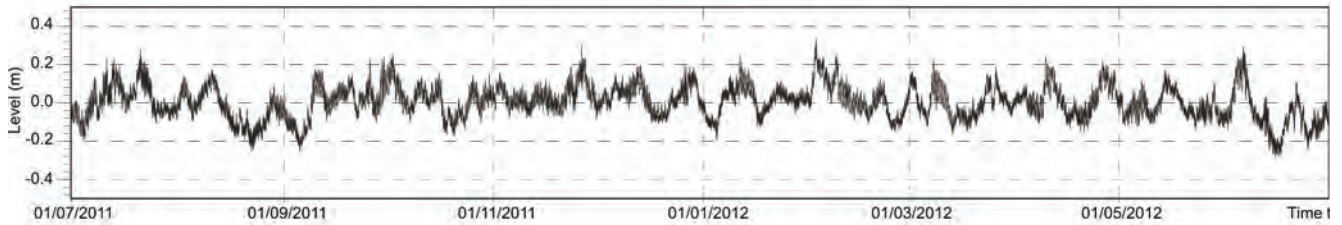
Hastings River, Port Macquarie



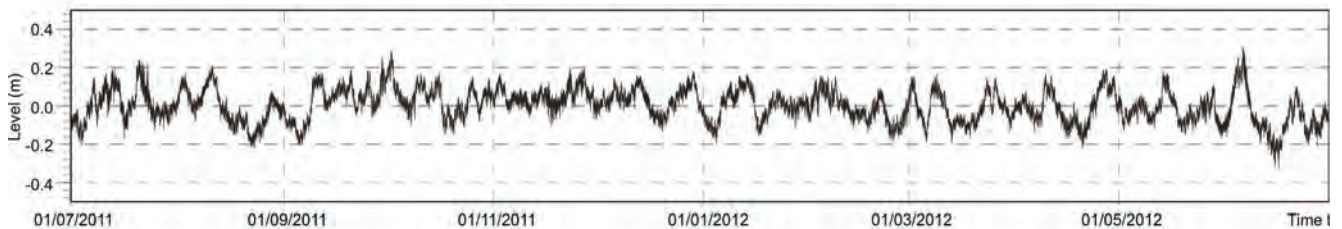
Tasman Sea at Crowdy Head Boat Harbour



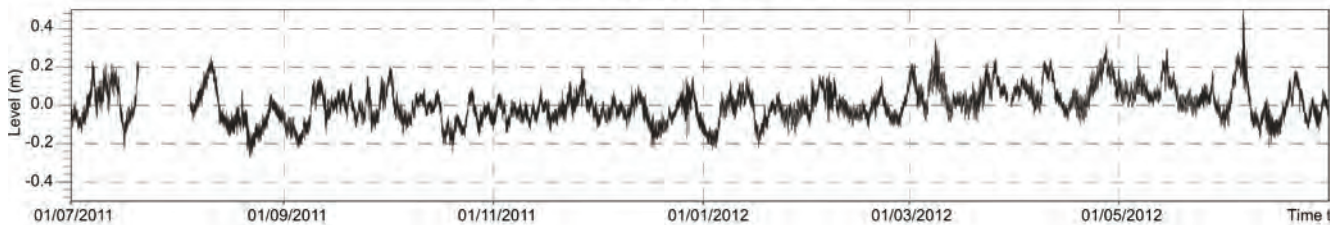
Wallis Lake Entrance at Forster



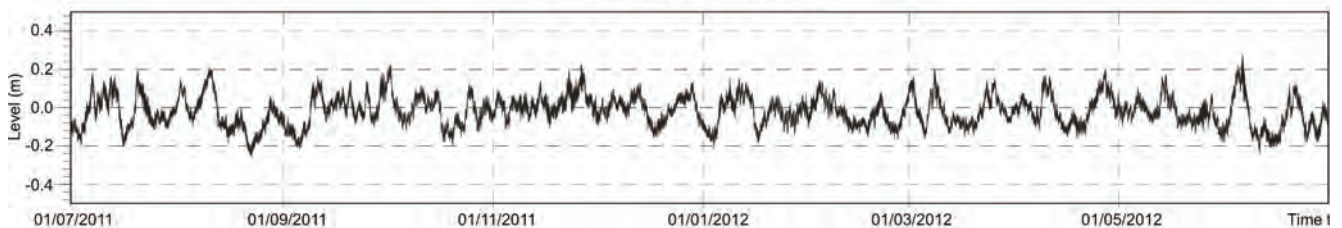
Port Stephens at Tomaree



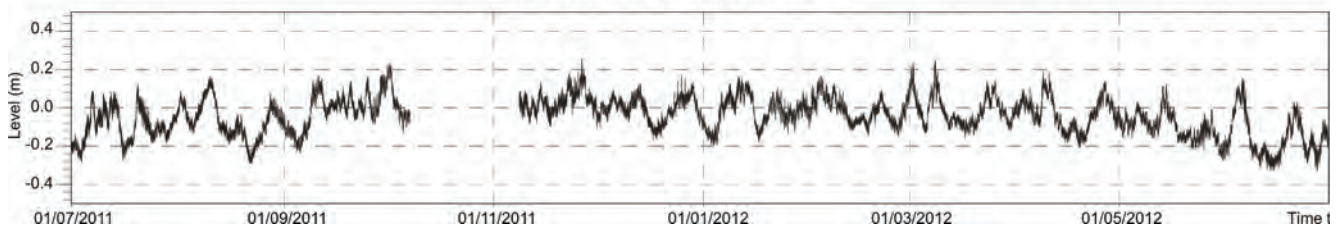
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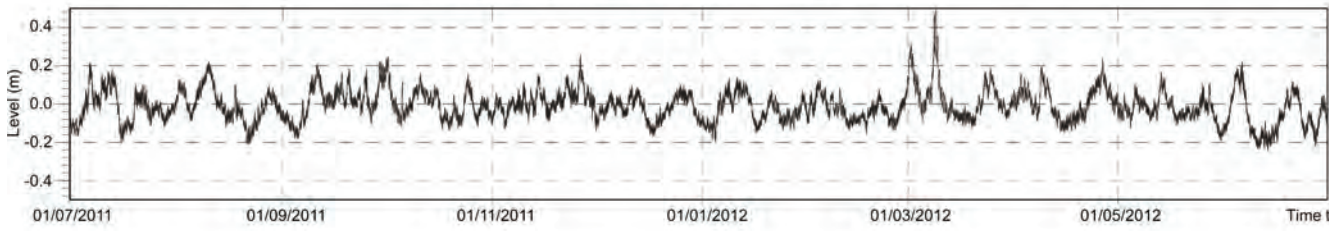
Port Jackson at Sydney



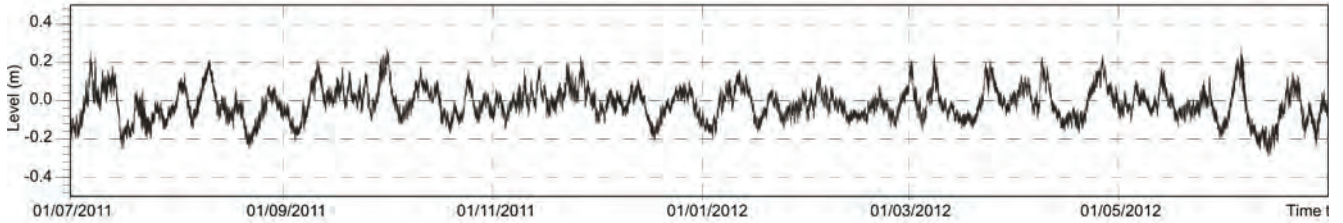
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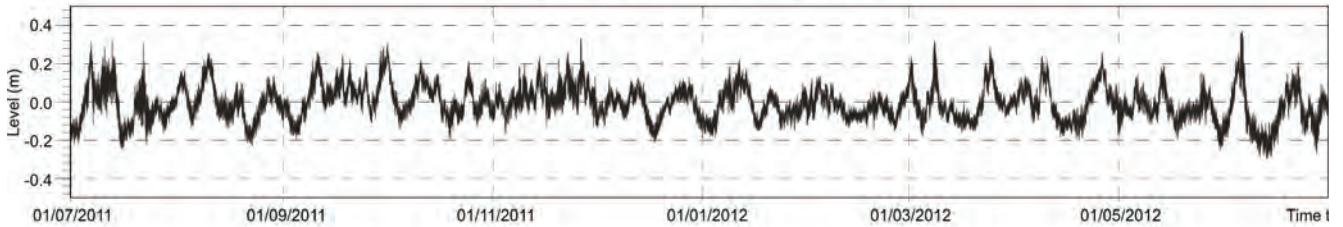
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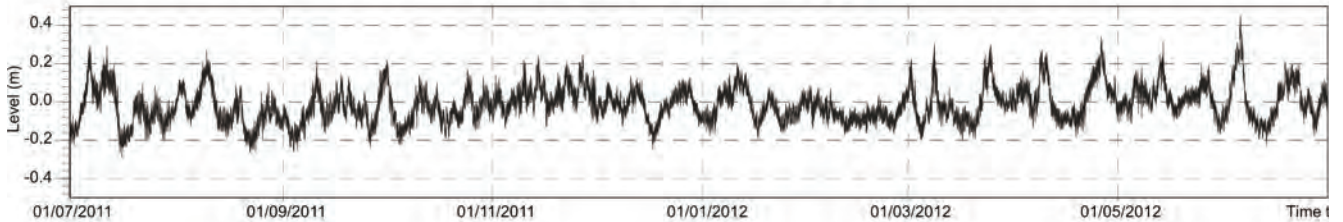
Jervis Bay at Jervis Bay



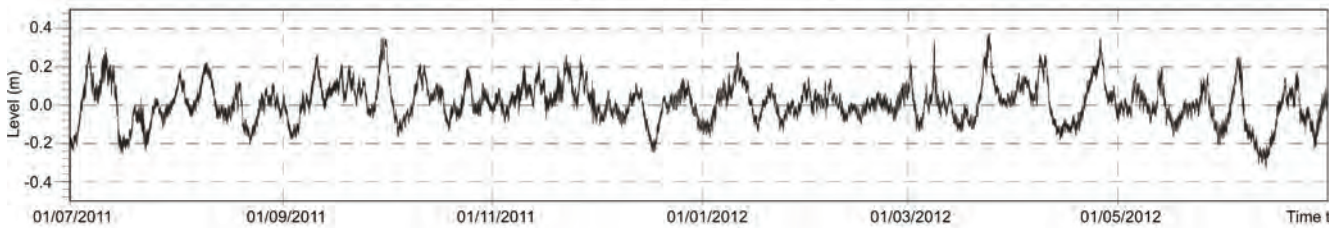
Tasman Sea at Ulladulla Boat Harbour



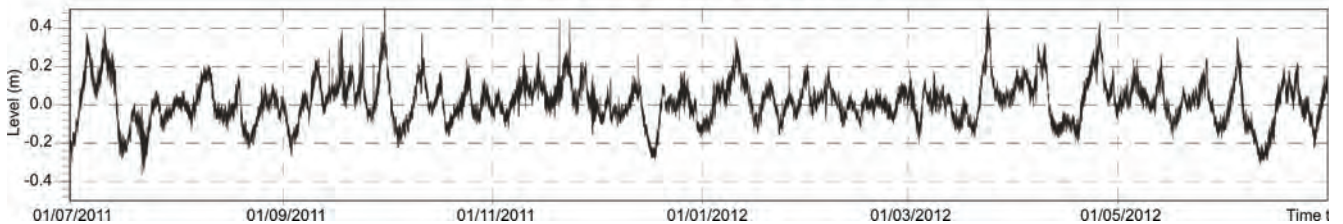
Princess Jetty at Batemans Bay



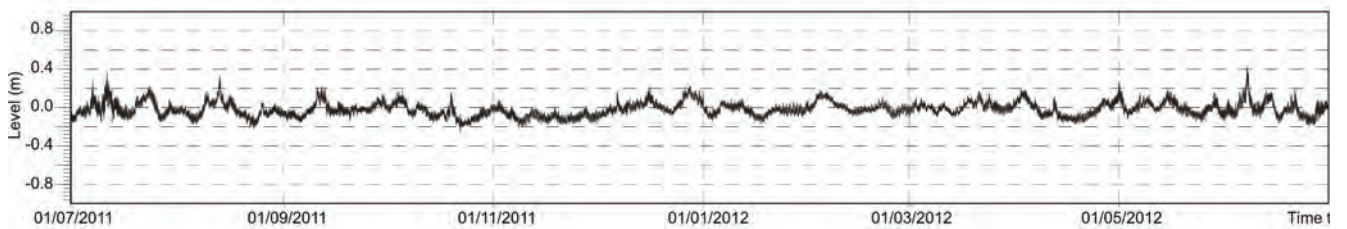
Bermagui Harbour at Bermagui



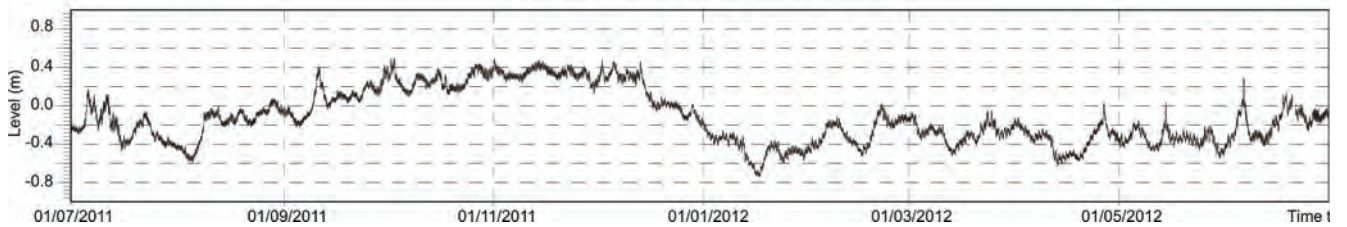
Tasman Sea at Eden Boat Harbour



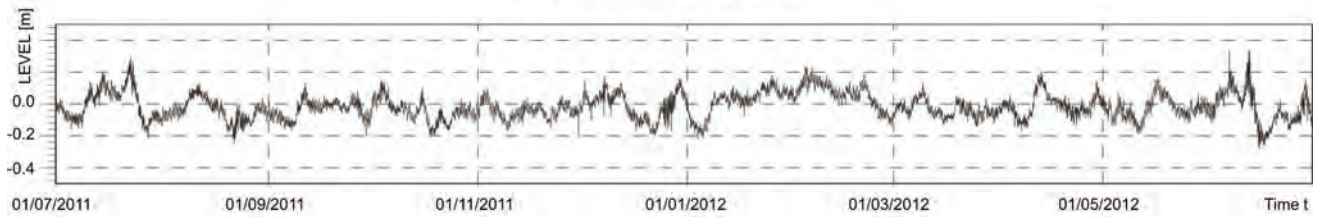
Tasman Sea at Norfolk Island



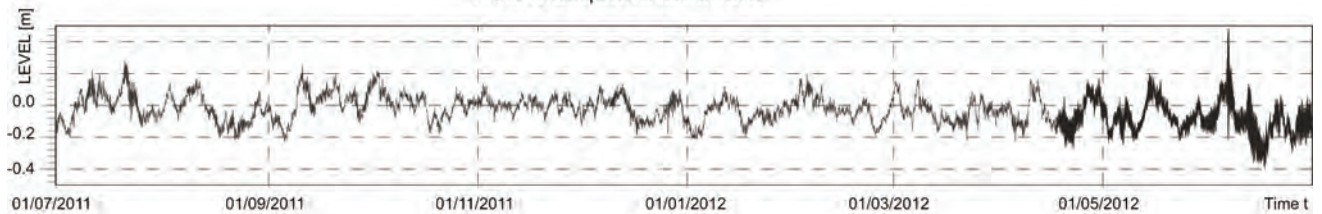
Tasman Sea at Lord Howe Island



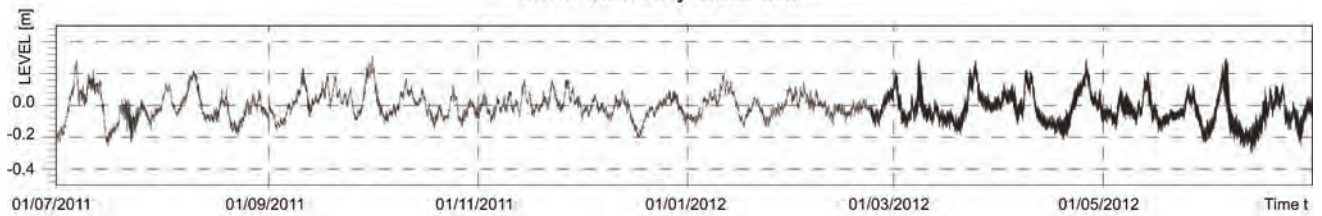
Tweed Heads Offshore



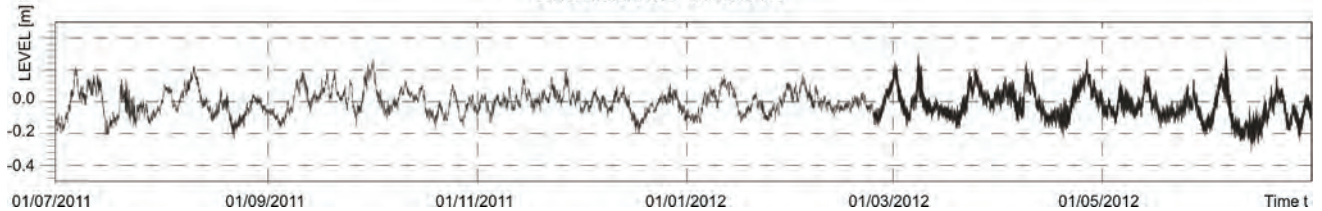
Port Macquarie Offshore

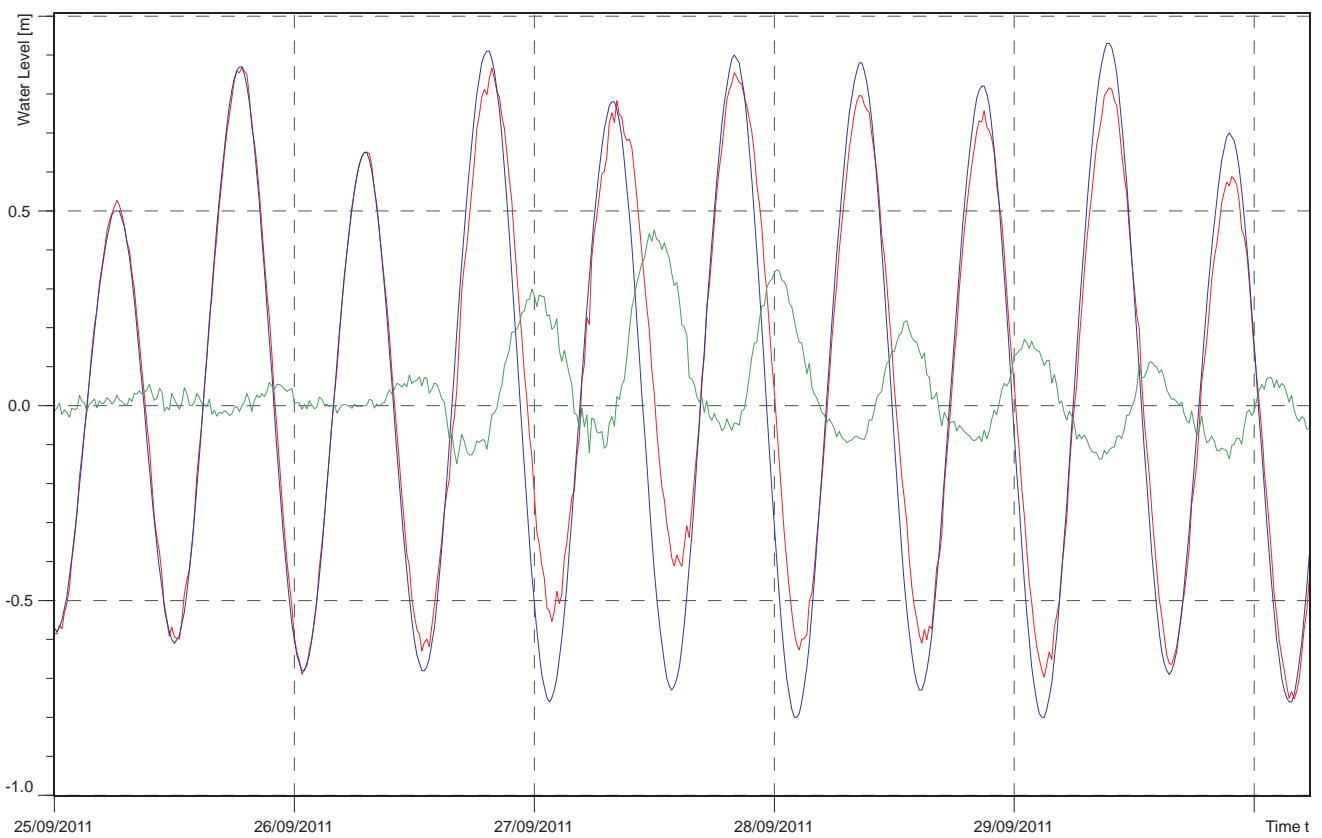


Batemans Bay Offshore



Shoalhaven Offshore





	Brunswick Heads Measured
	Brunswick Heads Forecast
	Brunswick Heads Residual



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**BRUNSWICK HEADS ANOMALY
SEPTEMBER 2011**

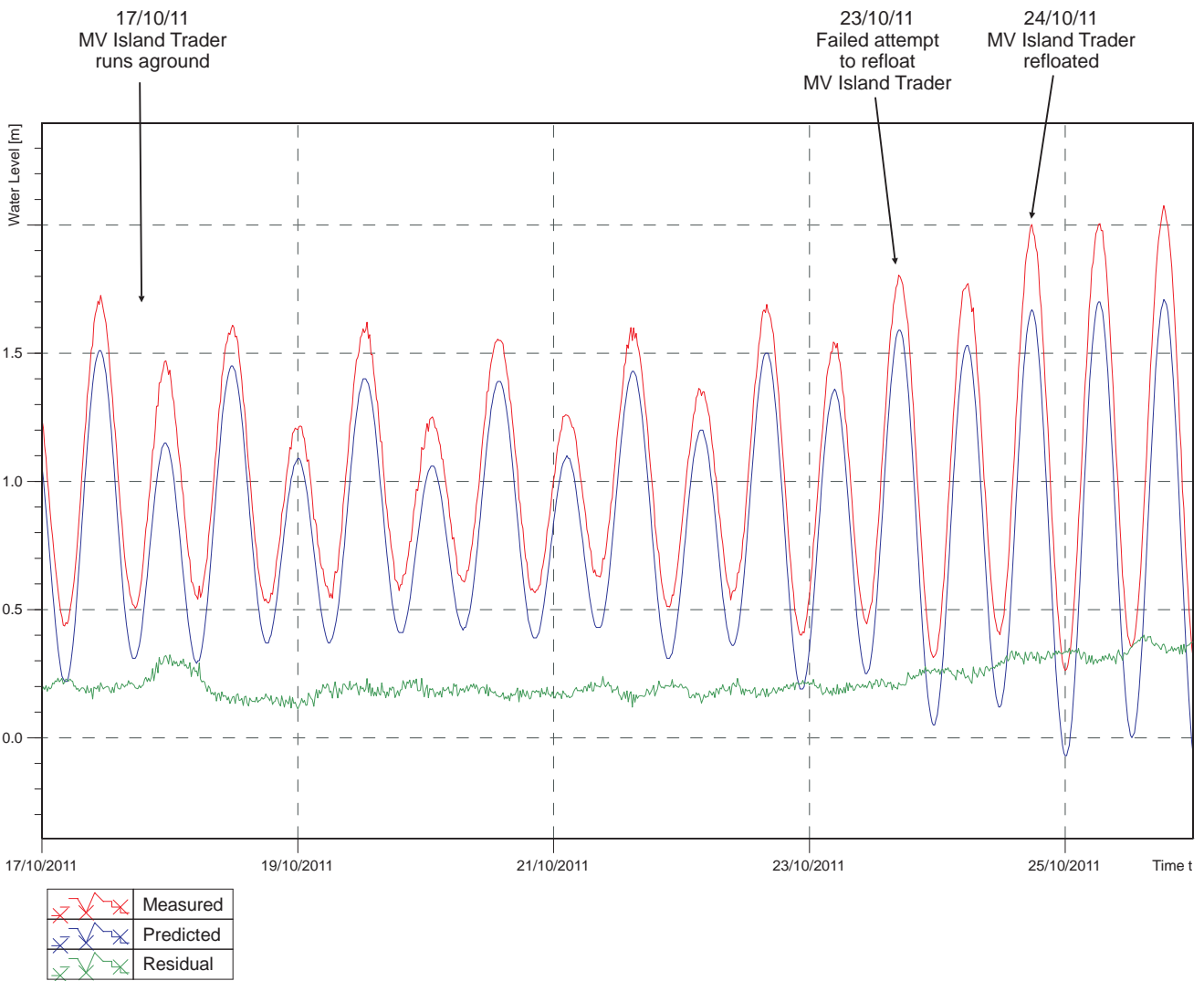
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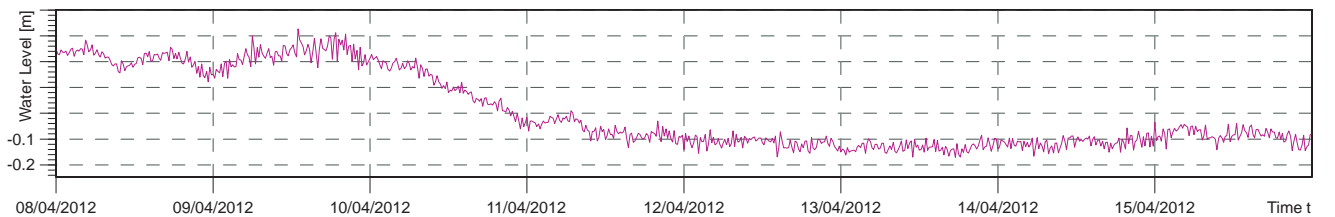
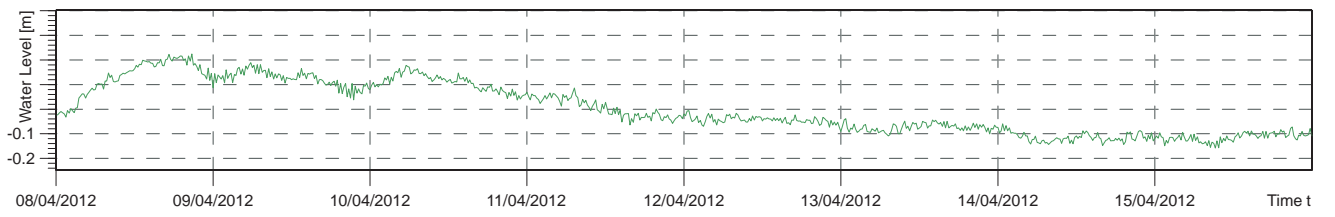
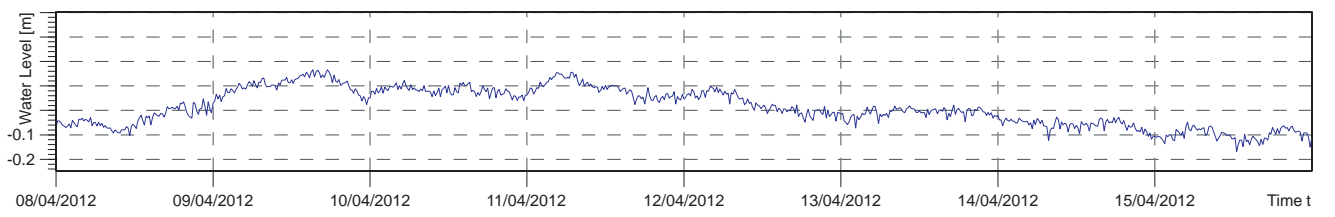
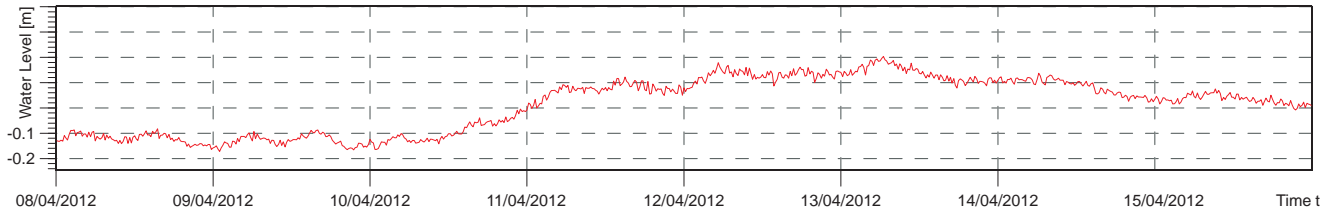
Figure
16

DRAWING 2158-16.cdr



Photo courtesy of Lord Howe Island Board





	Tweed Heads
	Port Stephens
	Jervis Bay
	Eden

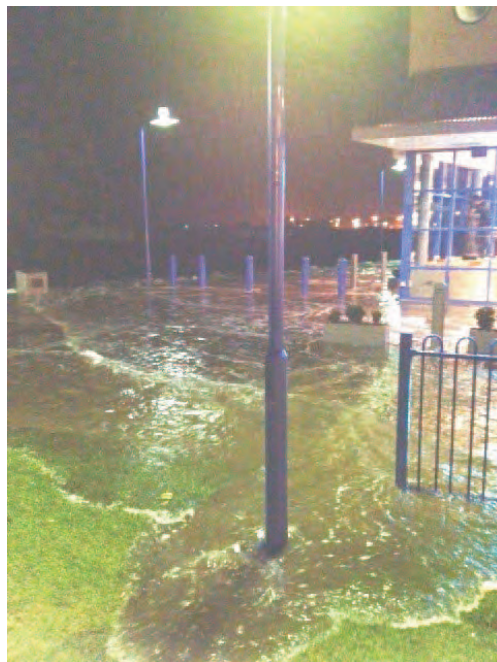




South Curl Curl Pool
photo: R Jacobs



Dee Why Pool
photo: W Taylor



Batemans Bay CBD boardwalk
photo: E Couriel



Dee Why Pool
photo: R Jacobs



Manly and Freshwater beaches
photo: M Callaghan



Gunnamatta Bay
photo: E Watson



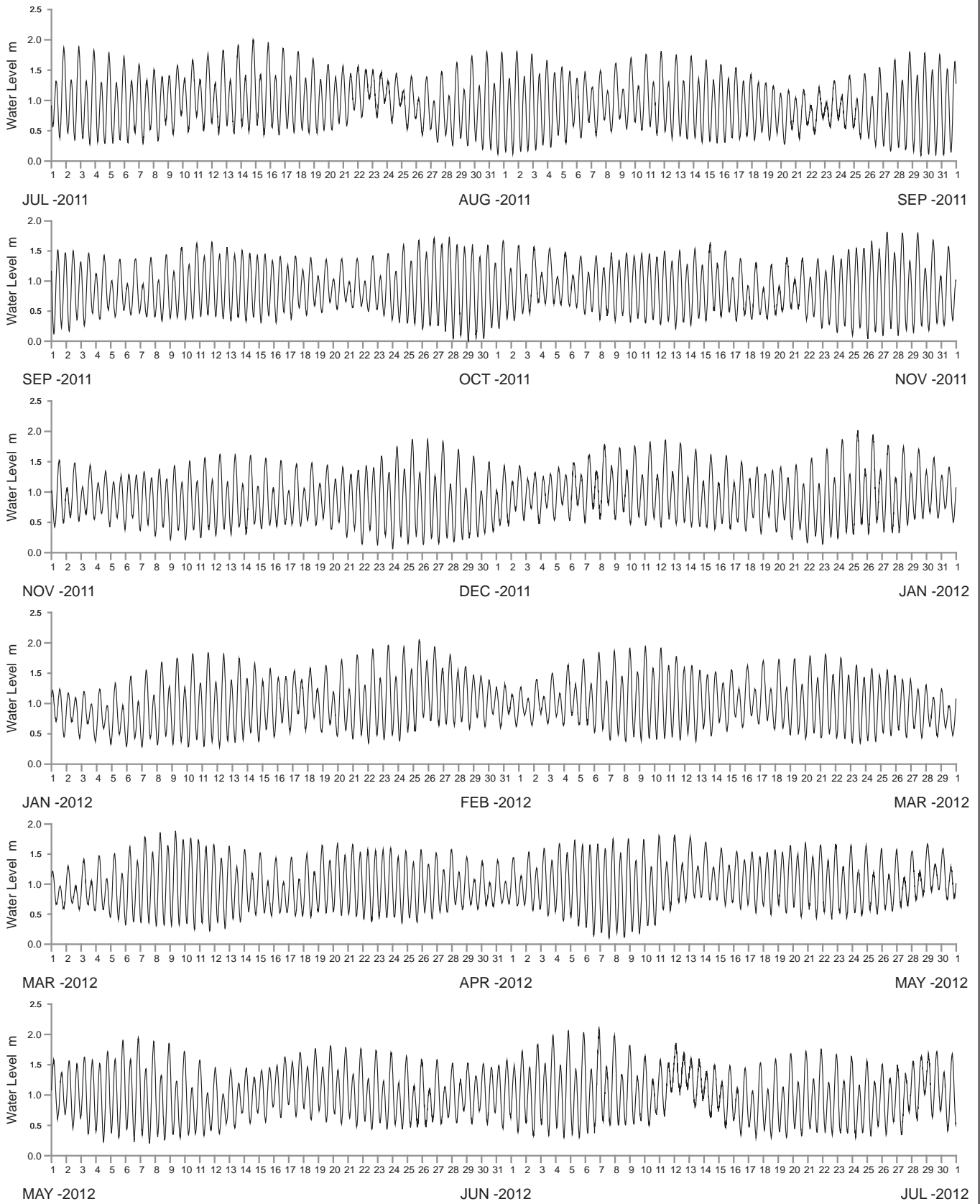
Public Works
Manly Hydraulics Laboratory

STATION LOCATION TWEED HEADS

MHL
Report 2158

Figure
21

DRAWING 2158-21.cdr



WATER LEVEL REFERENCED TO TWEED RIVER HYDRO DATUM





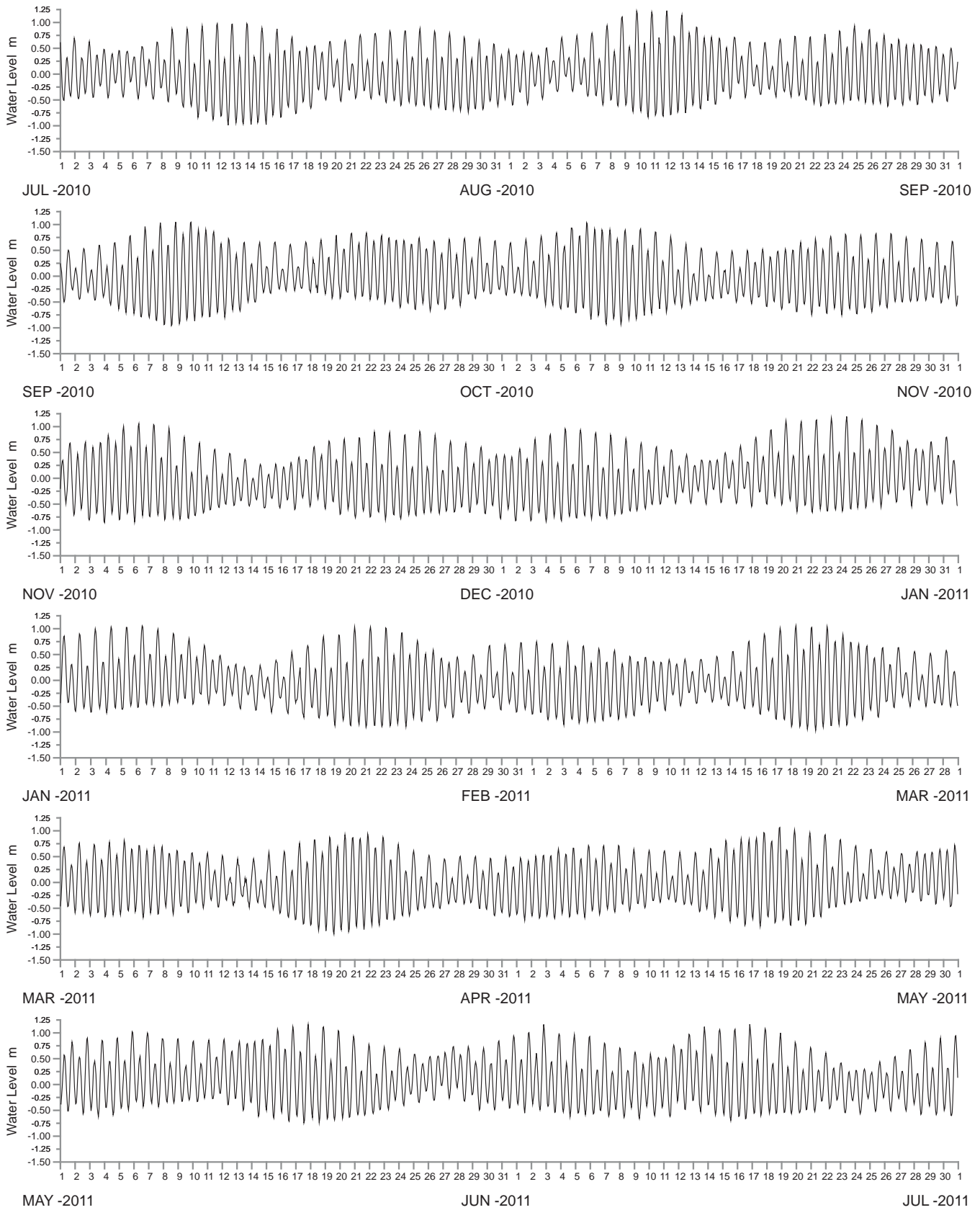
Public Works
Manly Hydraulics Laboratory

TWEED HEADS OFFSHORE TIDE GAUGE LOCATION

MHL
Report 2158

Figure
23

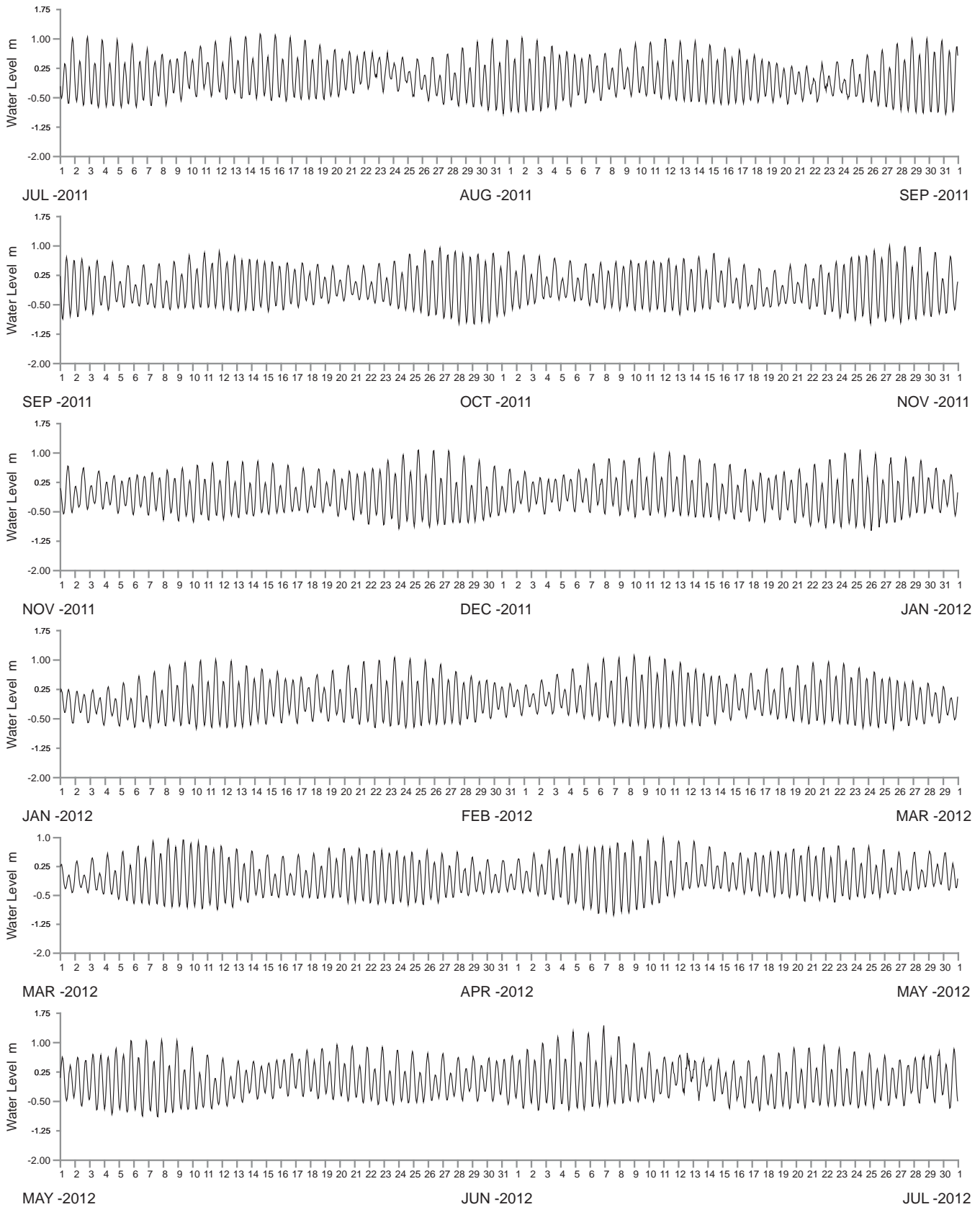
DRAWING 2158-23.cdr



WATER LEVEL REFERENCED TO MEAN SEA LEVEL



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WATER LEVEL REFERENCED TO MEAN SEA LEVEL



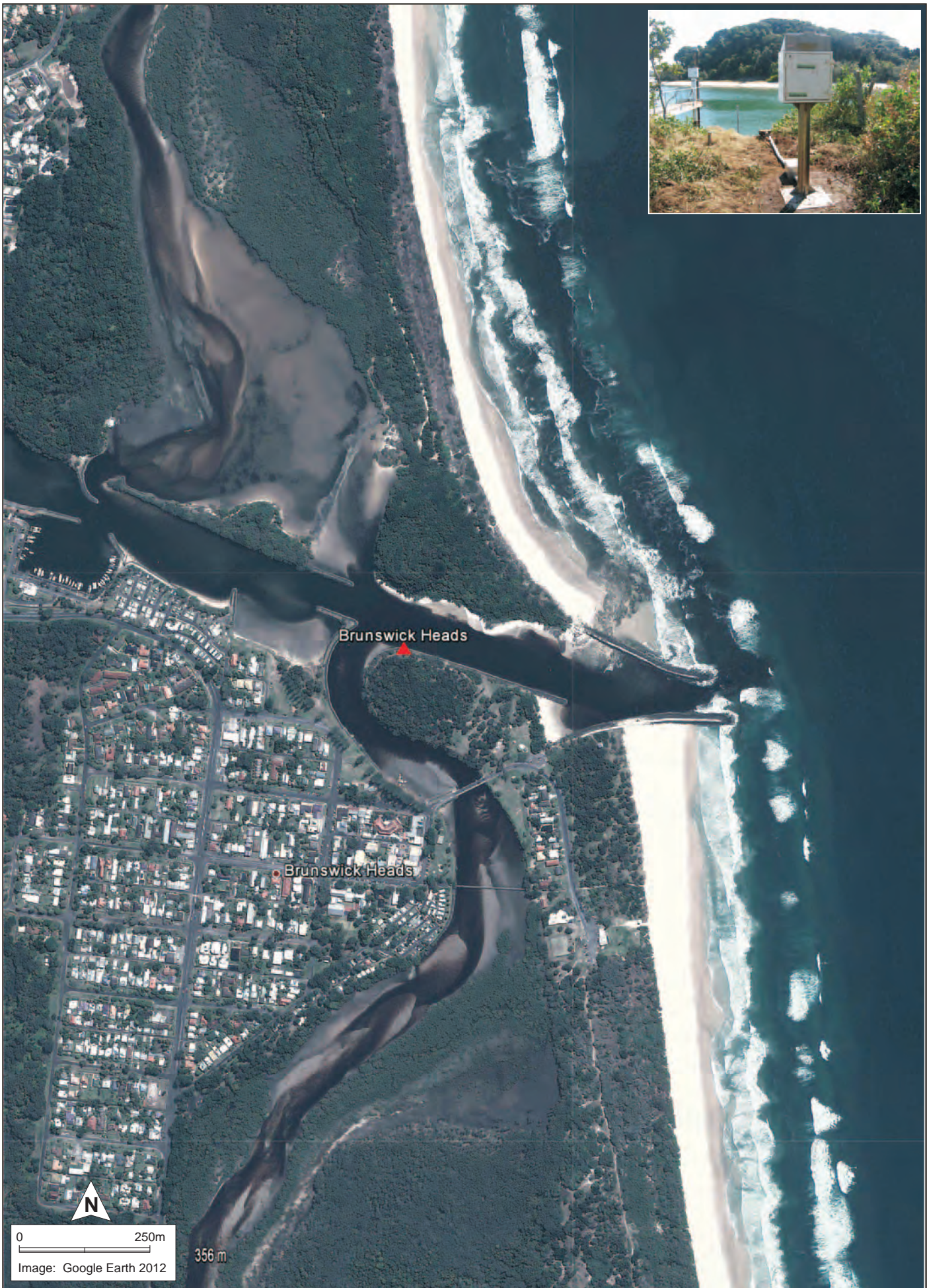
Public Works
Manly Hydraulics Laboratory

TASMAN SEA AT TWEED HEADS OFFSHORE
2011-2012

MHL
Report 2158

Figure
25

DRAWING 2158-25



Brunswick Heads

Brunswick Heads



0 250m
 Image: Google Earth 2012

356 m



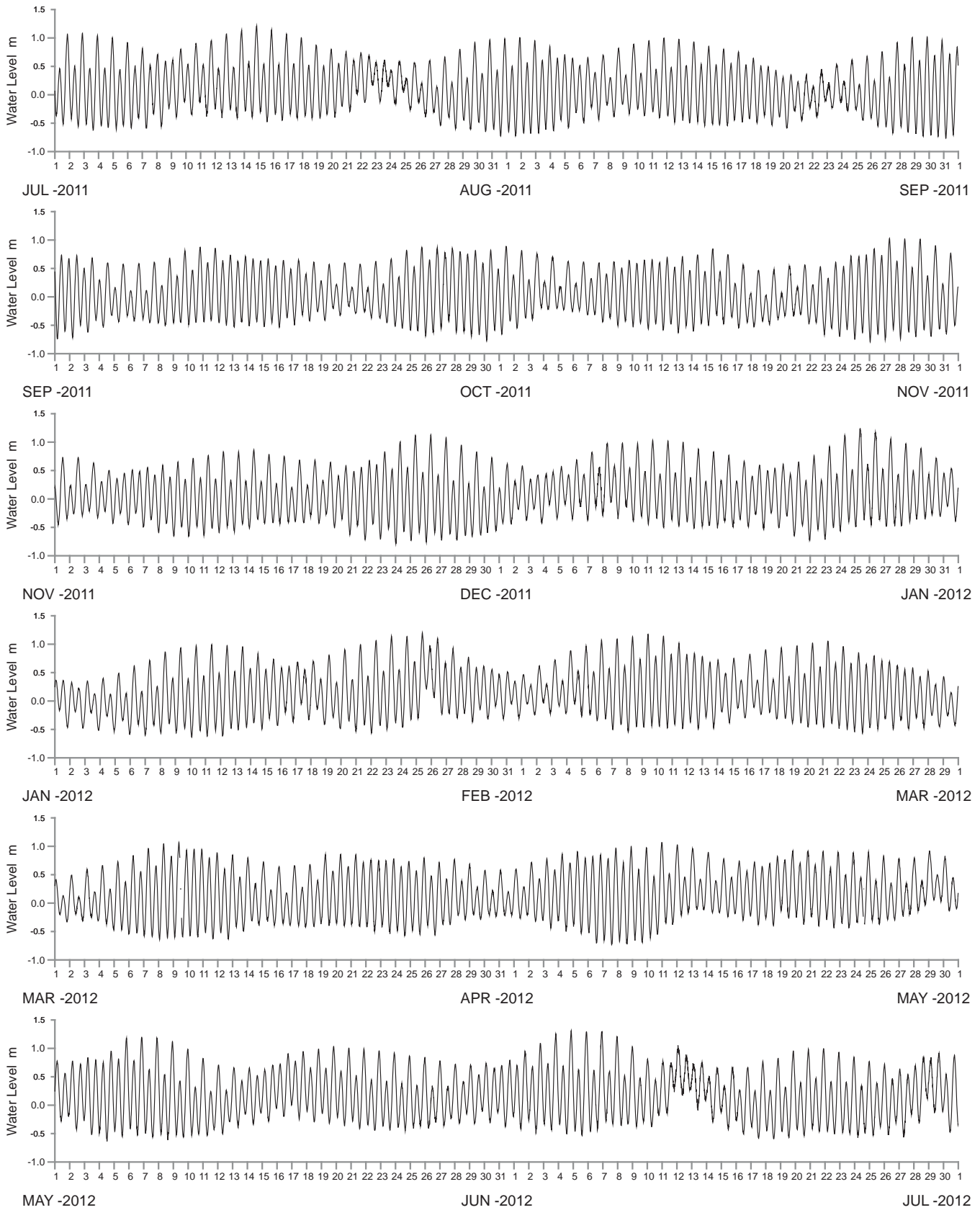
Public Works
 Manly Hydraulics Laboratory

**STATION LOCATION
 BRUNSWICK HEADS**

MHL
 Report 2158

**Figure
 26**

DRAWING 2158-26.cdr



WATER LEVEL REFERENCED TO BRUNSWICK RIVER FLOOD MITIGATION DATUM

----- DATA LOSS

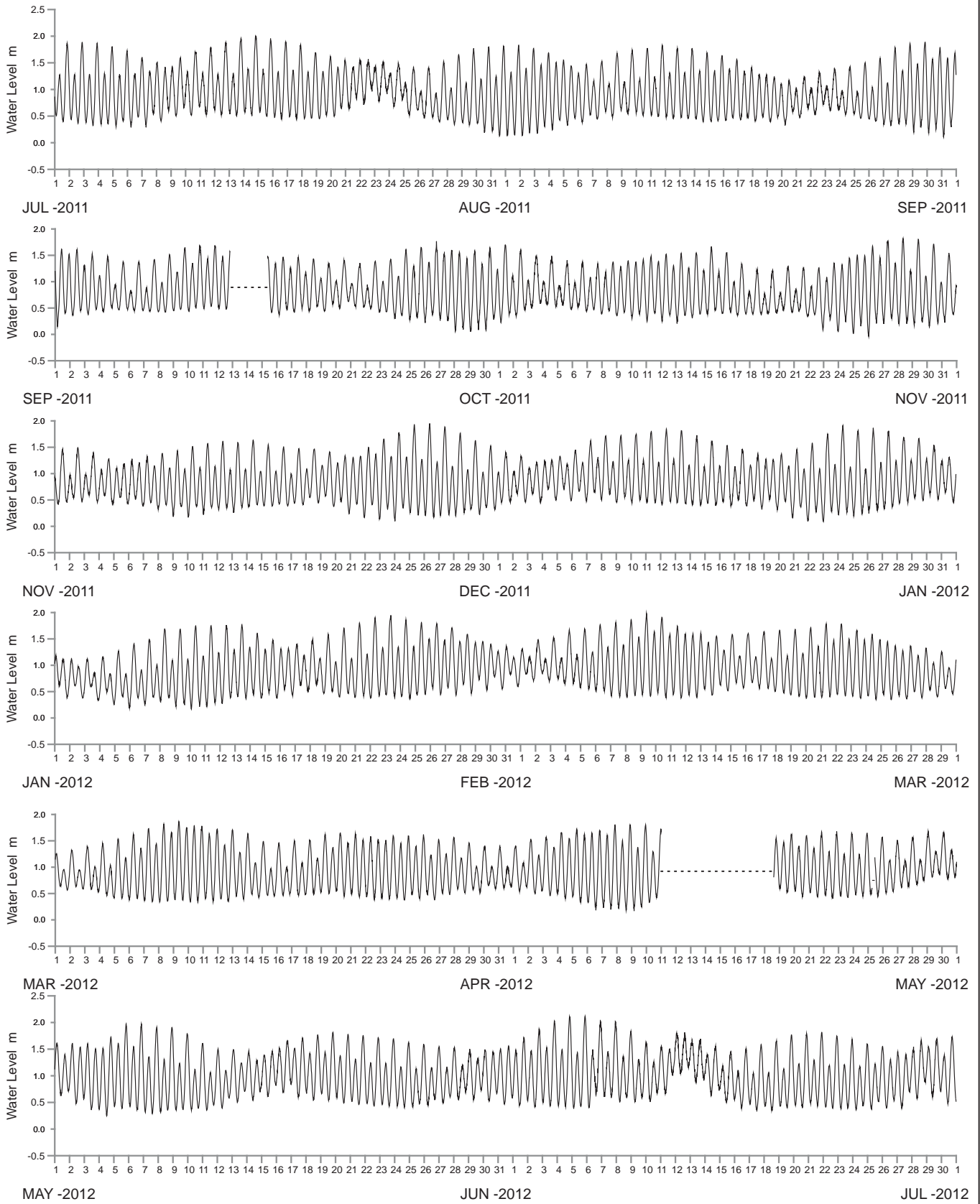


Public Works
Manly Hydraulics Laboratory

BRUNSWICK RIVER AT BRUNSWICK HEADS
2011-2012

MHL
Report 2158
Figure
27
DRAWING 2158-27





WATER LEVEL REFERENCED TO RICHMOND RIVER VALLEY DATUM

----- DATA LOSS



Public Works
Manly Hydraulics Laboratory

RICHMOND RIVER AT BALLINA BREAKWALL
2011-2012

MHL
Report 2158

Figure
29

DRAWING 2158-29



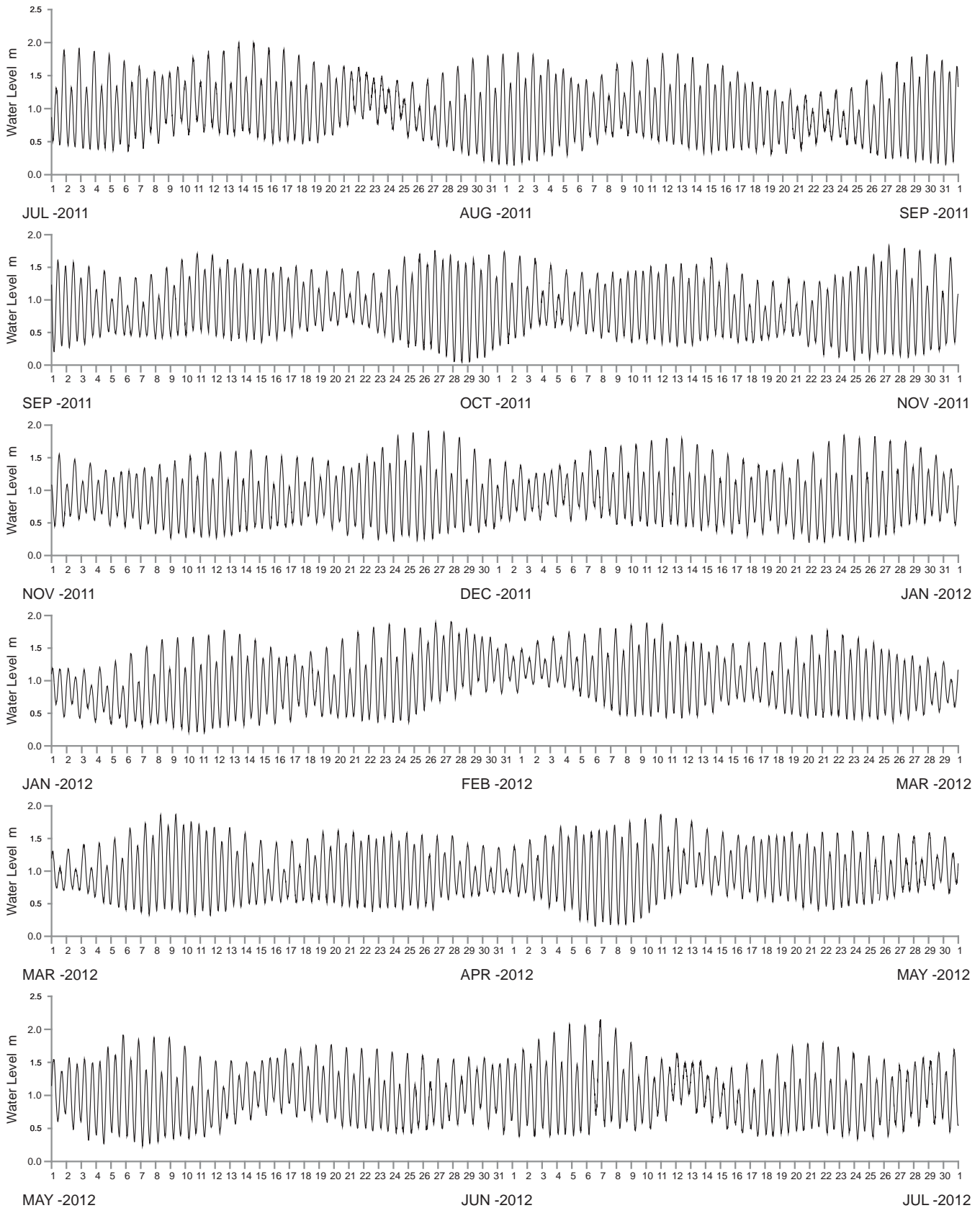
Public Works
Manly Hydraulics Laboratory

**STATION LOCATION
YAMBA**

MHL
Report 2158

**Figure
30**

DRAWING 2158-30.cdr



WATER LEVEL REFERENCED TO ILUKA PORT DATUM





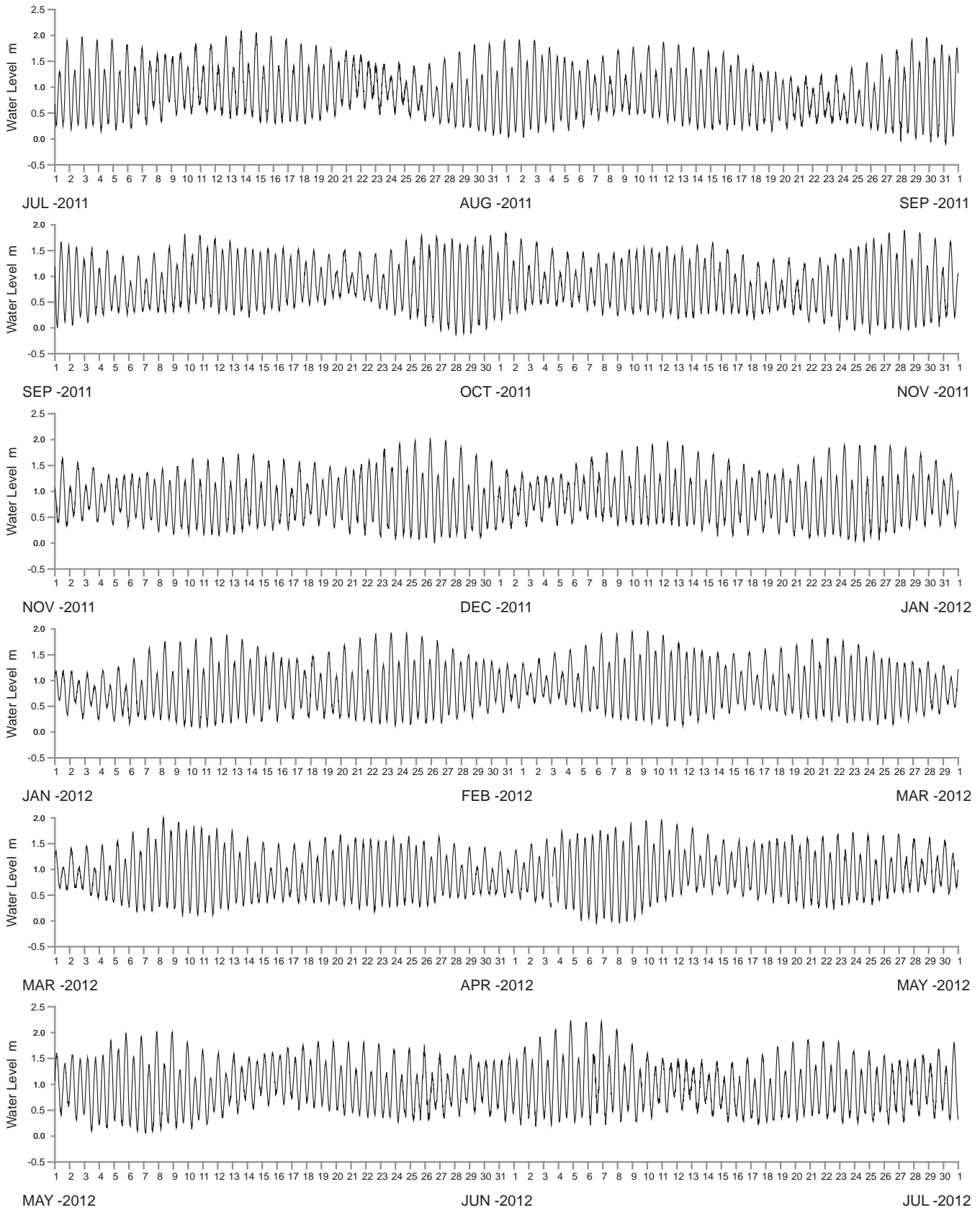
Public Works
Manly Hydraulics Laboratory

**STATION LOCATION
COFFS HARBOUR**

MHL
Report 2158

**Figure
32**

DRAWING 2158-32.cdr



WATER LEVEL REFERENCED TO COFFS PORT DATUM



Public Works
Manly Hydraulics Laboratory

TASMAN SEA AT COFFS HARBOUR
2011-2012

MHL
Report 2158

Figure
33

DRAWING 2158-33



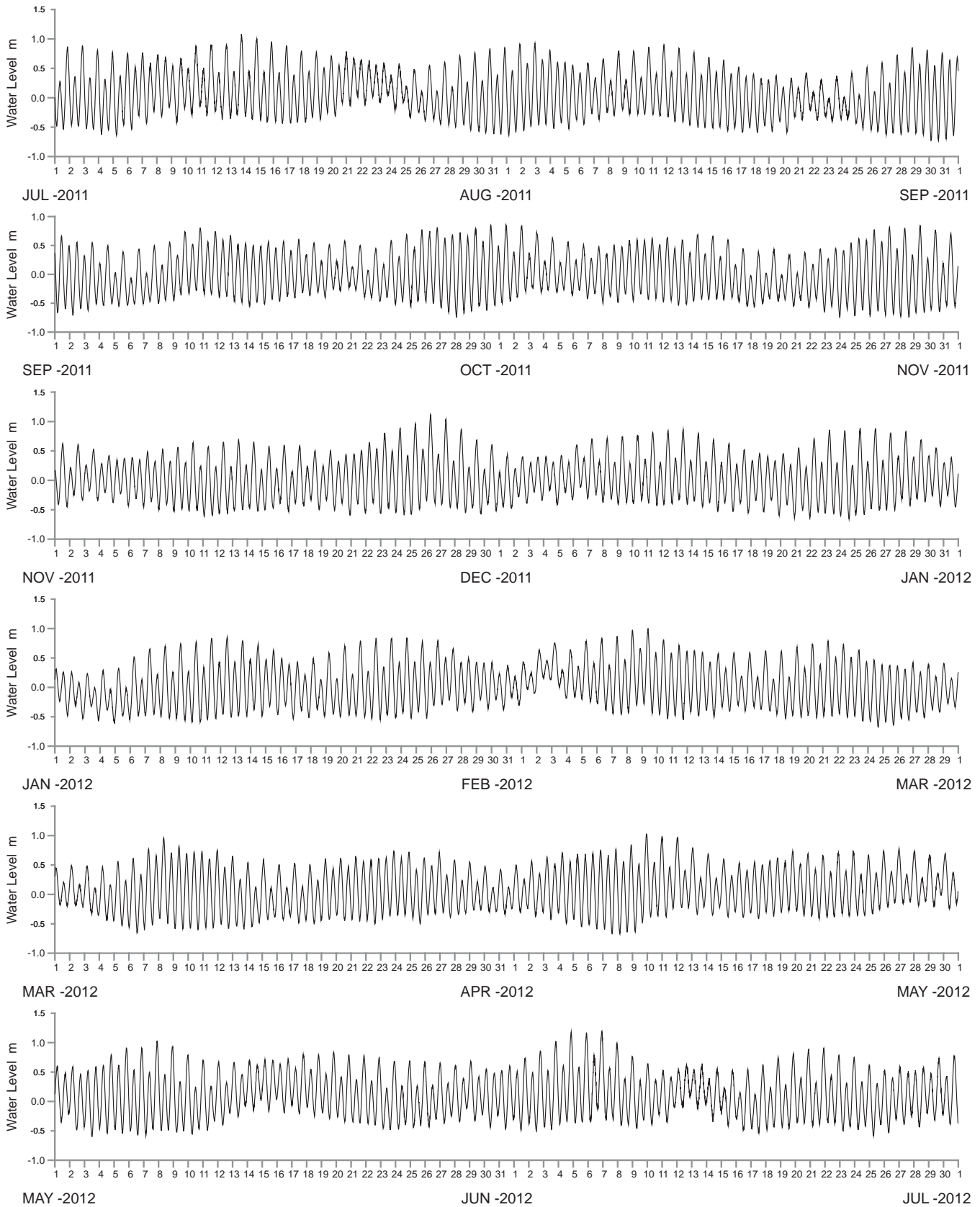
Public Works
Manly Hydraulics Laboratory

**STATION LOCATION
PORT MACQUARIE**

MHL
Report 2158

**Figure
34**

DRAWING 2158-34.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM



Public Works
Manly Hydraulics Laboratory

HASTINGS RIVER AT PORT MACQUARIE
2011-2012

MHL
Report 2158

Figure
35

DRAWING 2158-35



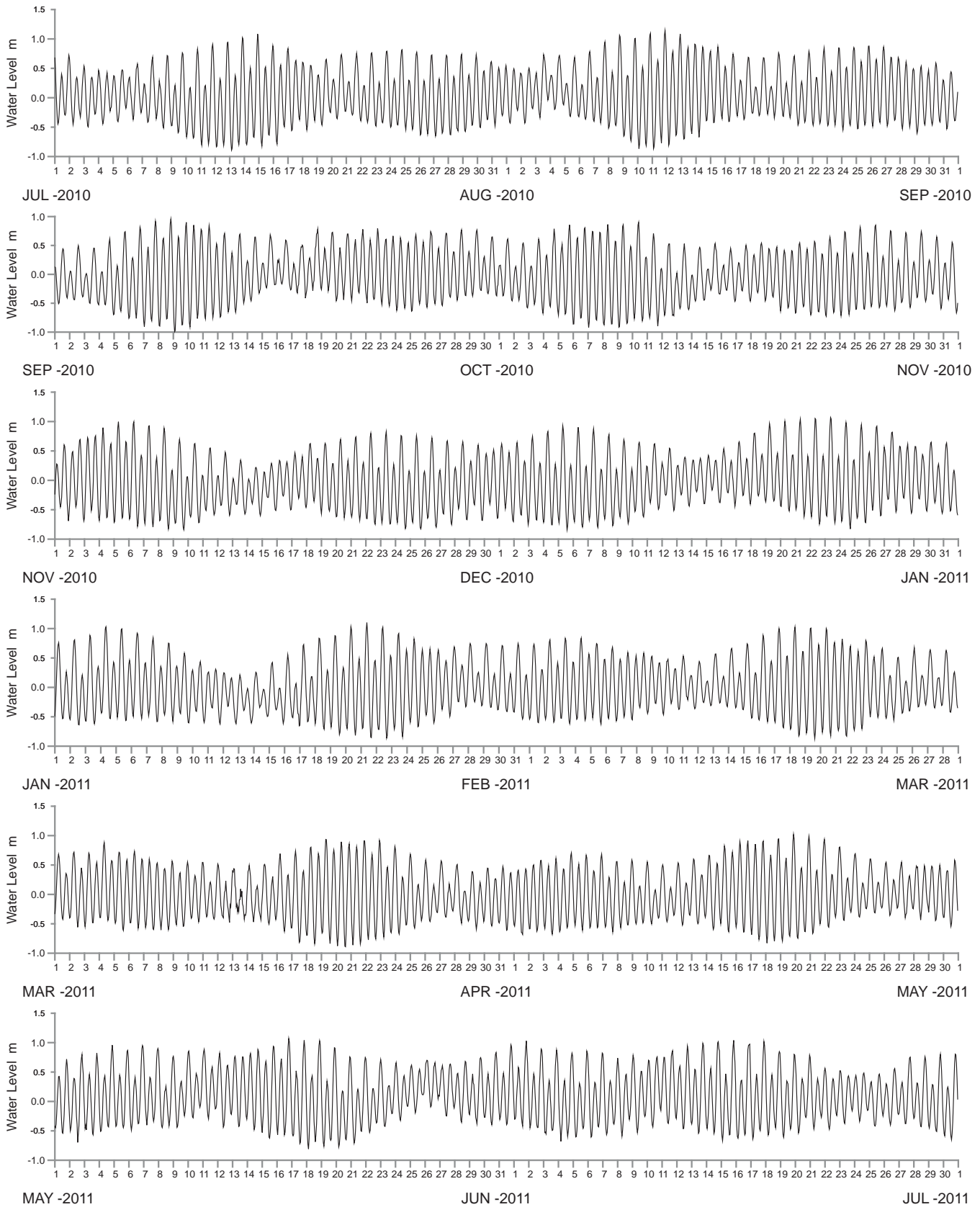
Public Works
Manly Hydraulics Laboratory

**PORT MACQUARIE
OFFSHORE TIDE GAUGE LOCATION**

MHL
Report 2158

Figure
36

DRAWING 2158-36.cdr



WATER LEVEL REFERENCED TO MEAN SEA LEVEL



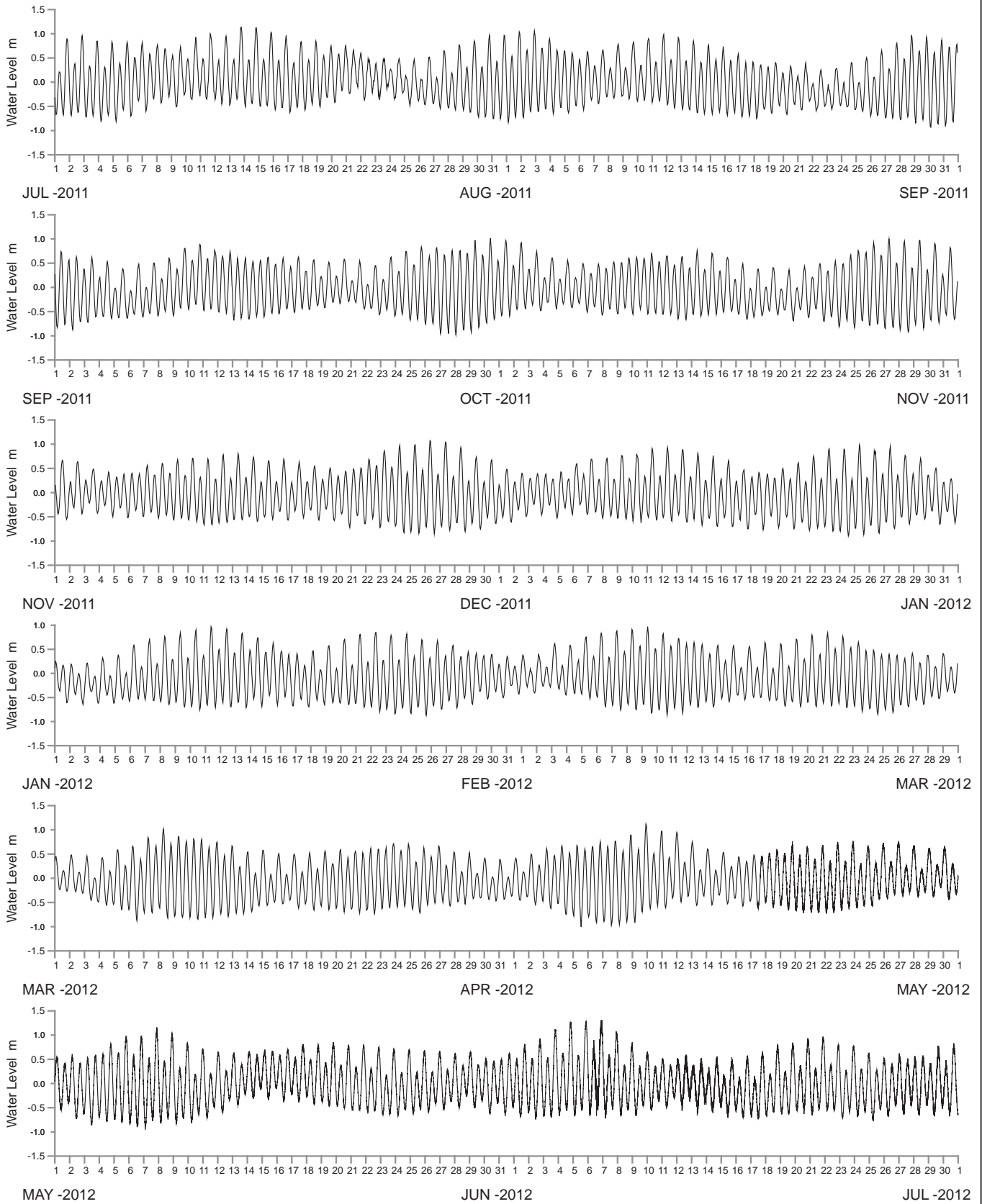
Public Works
Manly Hydraulics Laboratory

TASMAN SEA AT PORT MACQUARIE OFFSHORE
2010-2011

MHL
Report 2158
Figure
37

DRAWING 2158-37

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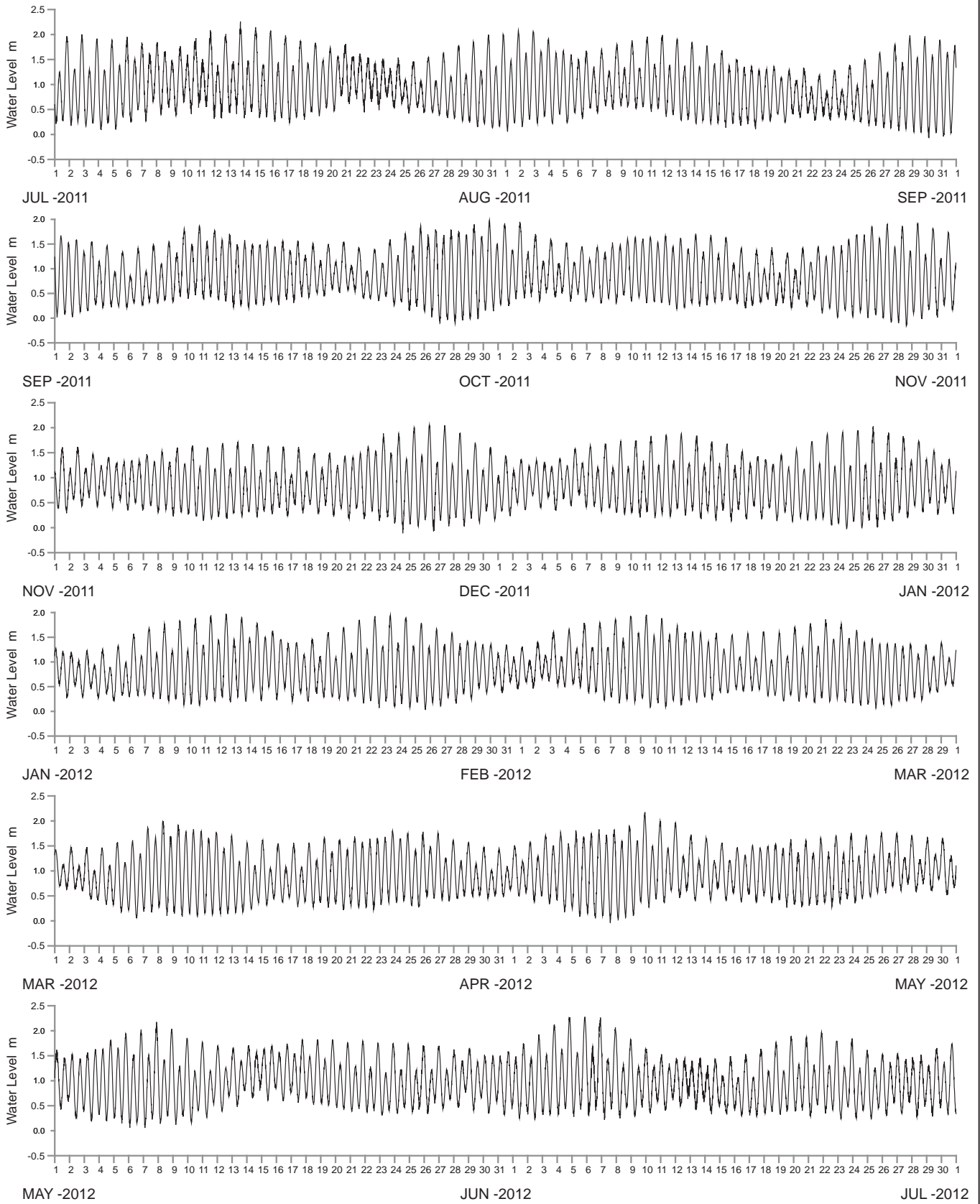
WATER LEVEL REFERENCED TO MEAN SEA LEVEL





0 500m

Image: Google Earth 2012



WATER LEVEL REFERENCED TO CROWDY HEAD DATUM



Public Works
Manly Hydraulics Laboratory

TASMAN SEA AT CROWDY HEAD BOAT HARBOUR
2011-2012

MHL
Report 2158

Figure
40

DRAWING 2158-40



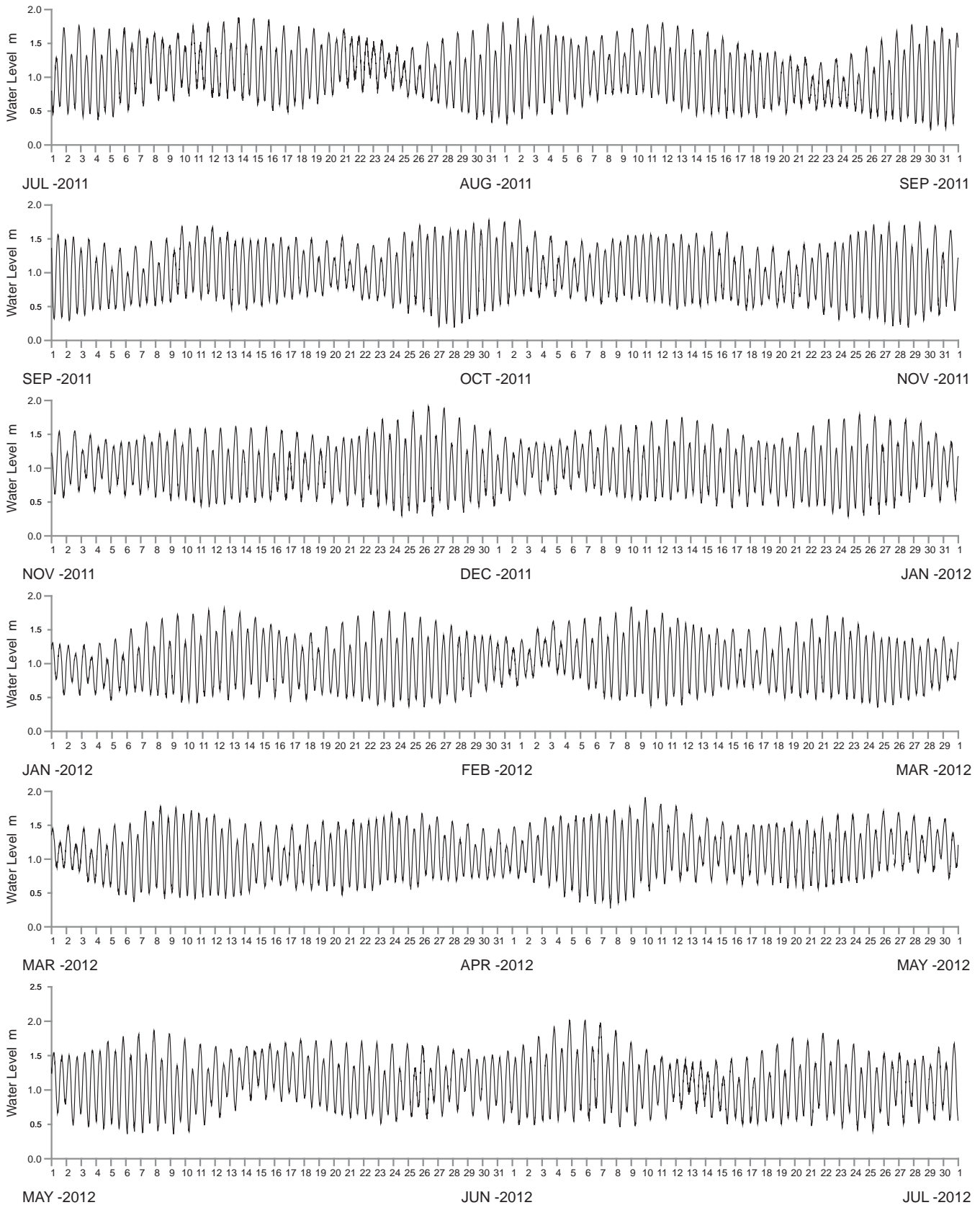
Public Works
Manly Hydraulics Laboratory

STATION LOCATION FORSTER

MHL
Report 2158

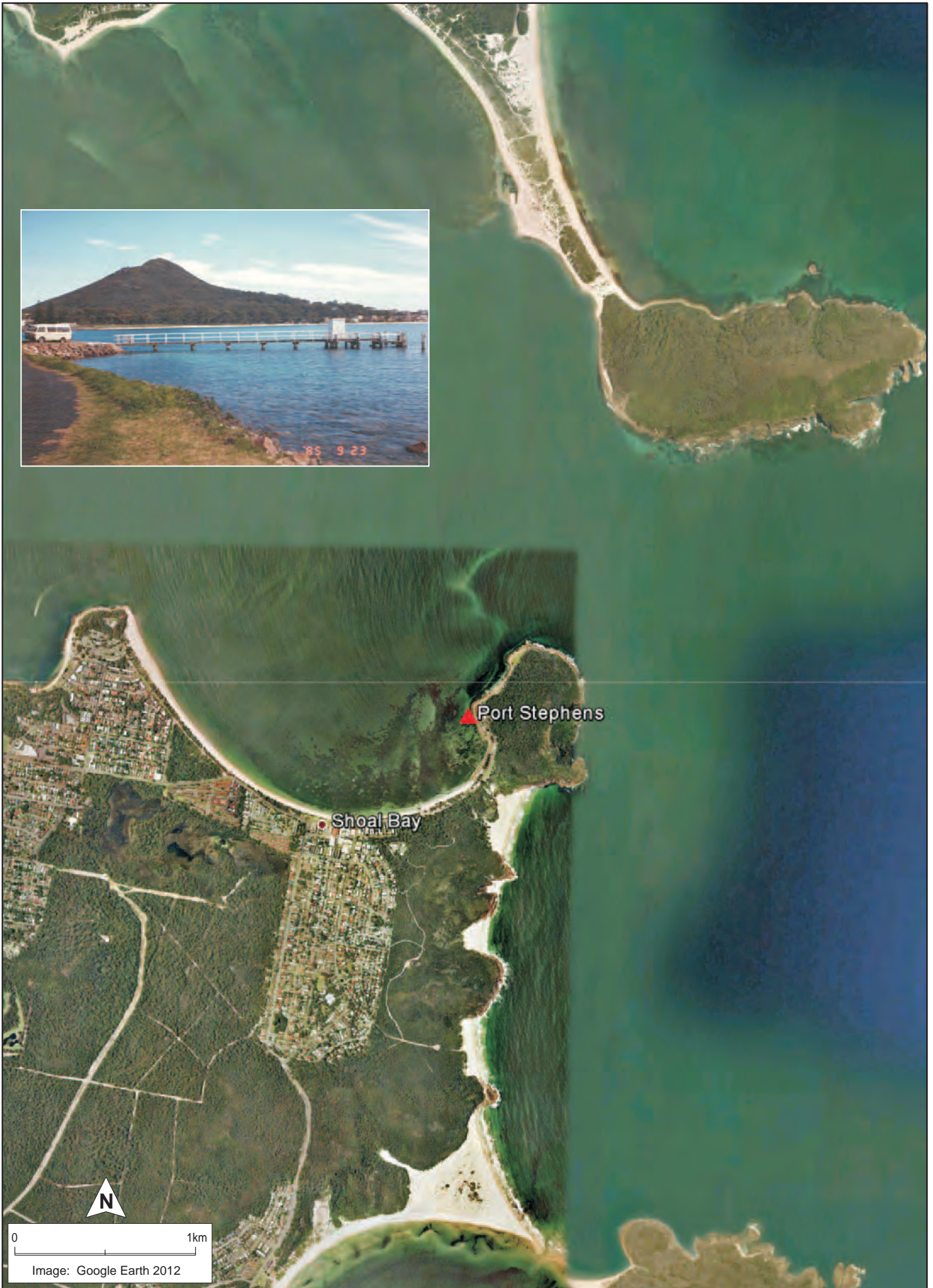
Figure
41

DRAWING 2158-41.cdr



WATER LEVEL REFERENCED TO FORSTER HYDRO DATUM





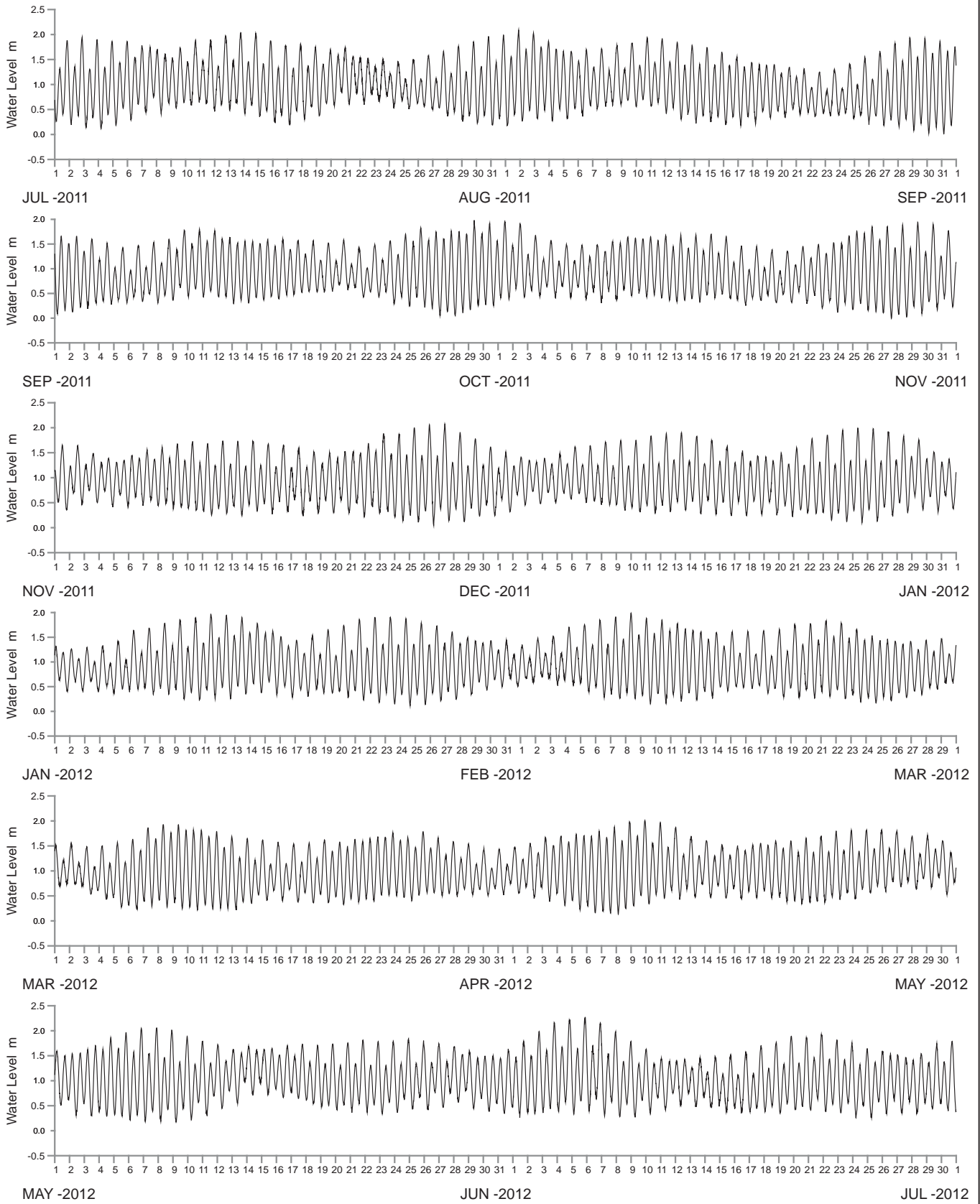
Public Works
Manly Hydraulics Laboratory

**STATION LOCATION
PORT STEPHENS**

MHL
Report 2158

**Figure
43**

DRAWING 2158-43.cdr

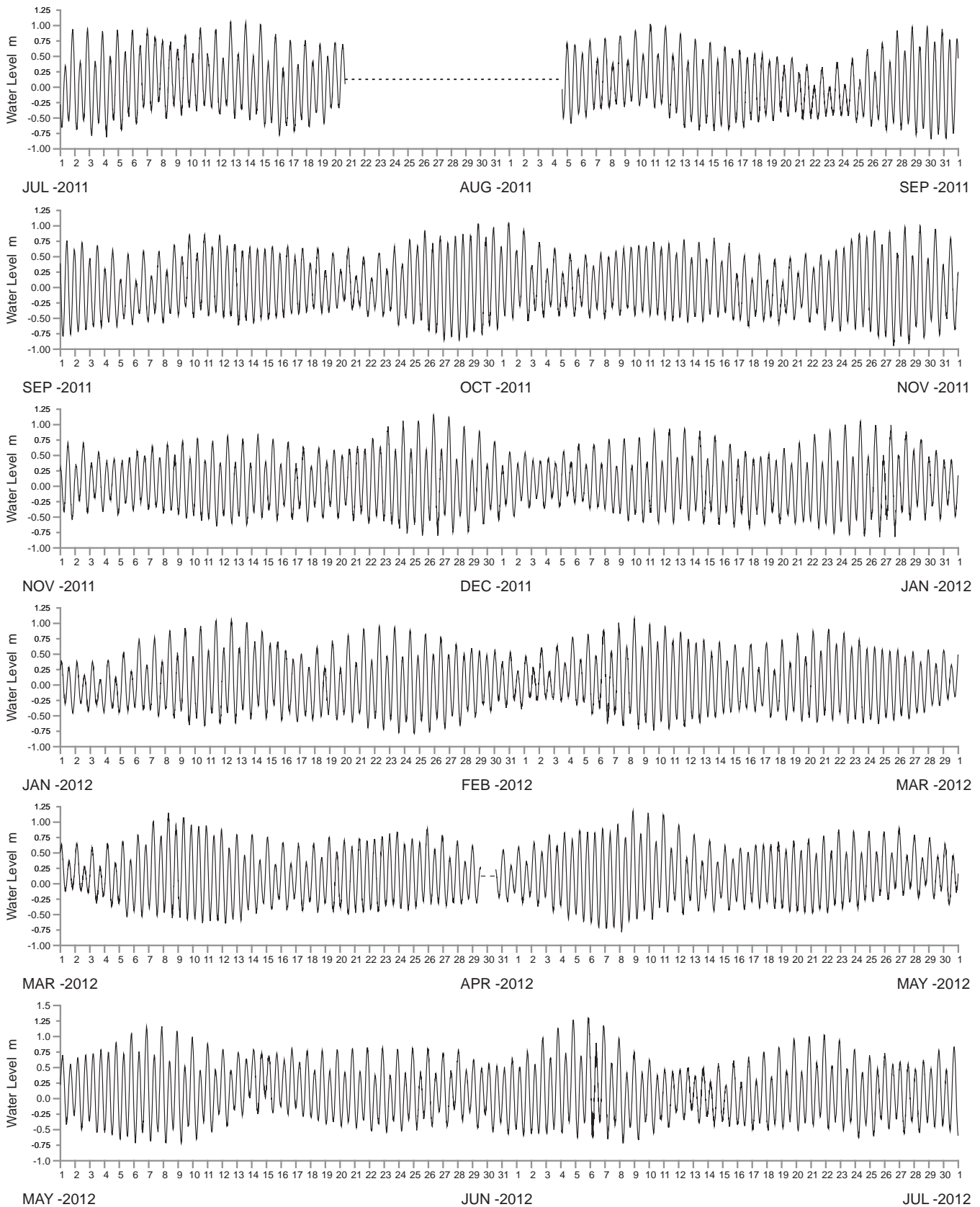


WATER LEVEL REFERENCED TO PORT STEPHENS HYDRO DATUM





0 2km
Image: Google Earth 2012



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



Public Works
Manly Hydraulics Laboratory

HAWKESBURY RIVER AT PATONGA
2011-2012

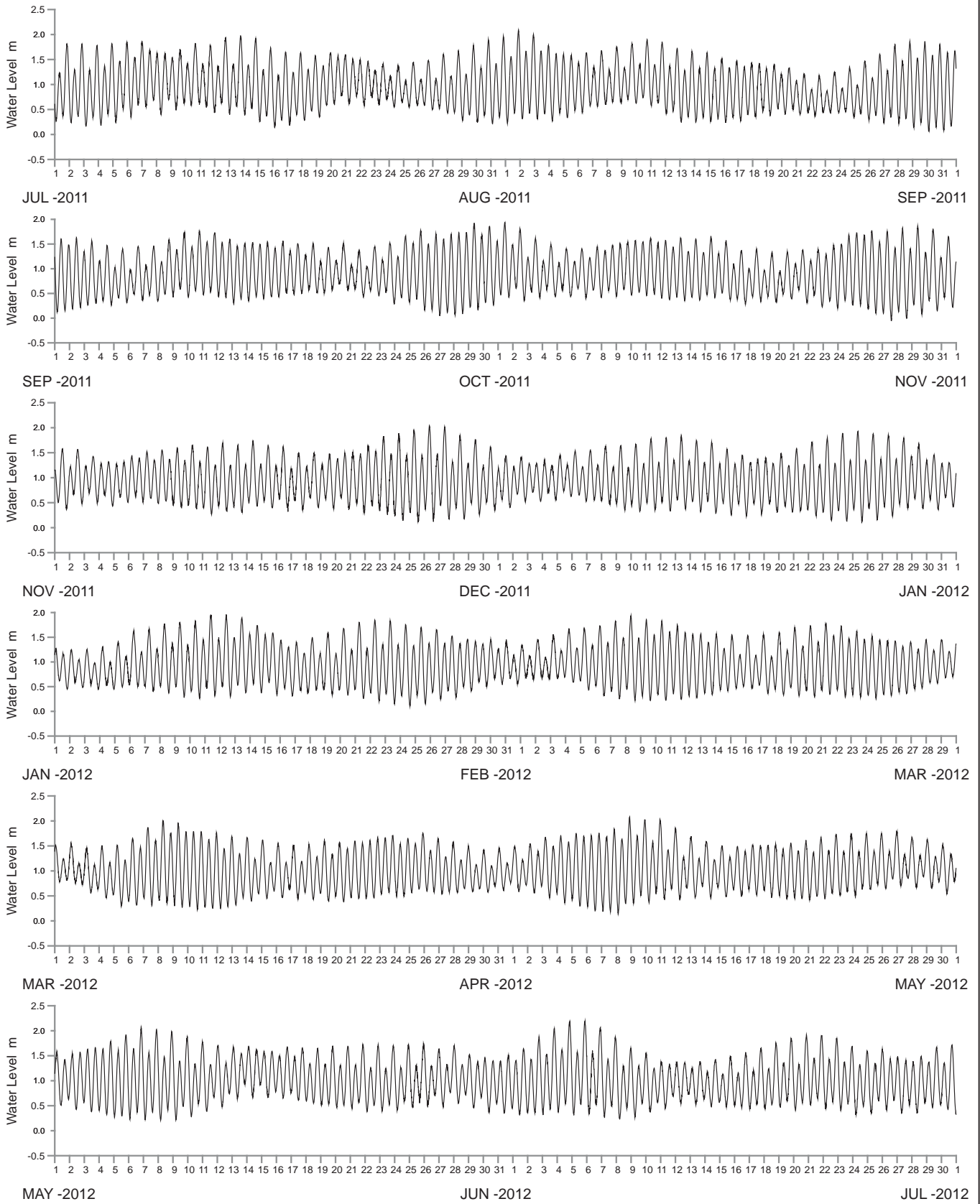
MHL
Report 2158

Figure
46

DRAWING 2158-46



0 2km
 Image: Google Earth 2012



WATER LEVEL REFERENCED TO ZERO CAMP COVE





0 1km
Image: Google Earth 2012



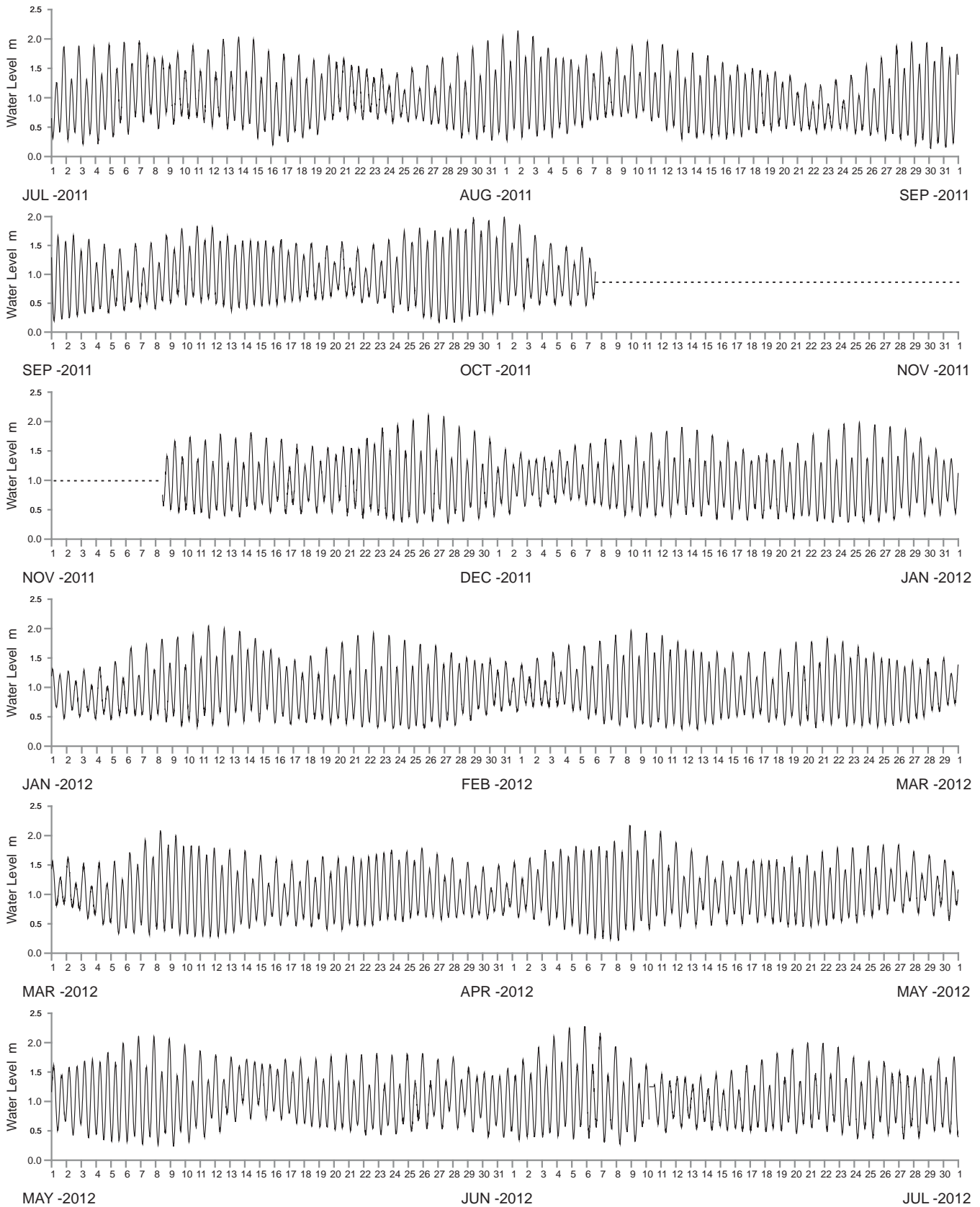
Public Works
Manly Hydraulics Laboratory

STATION LOCATION PORT HACKING

MHL
Report 2158

Figure
49

DRAWING 2158-49.cdr



WATER LEVEL REFERENCED TO INDIAN SPRING LOW WATER

----- DATA LOSS



Public Works
Manly Hydraulics Laboratory

PORT HACKING AT PORT HACKING
2011-2012

MHL
Report 2158

Figure
50

DRAWING 2158-50



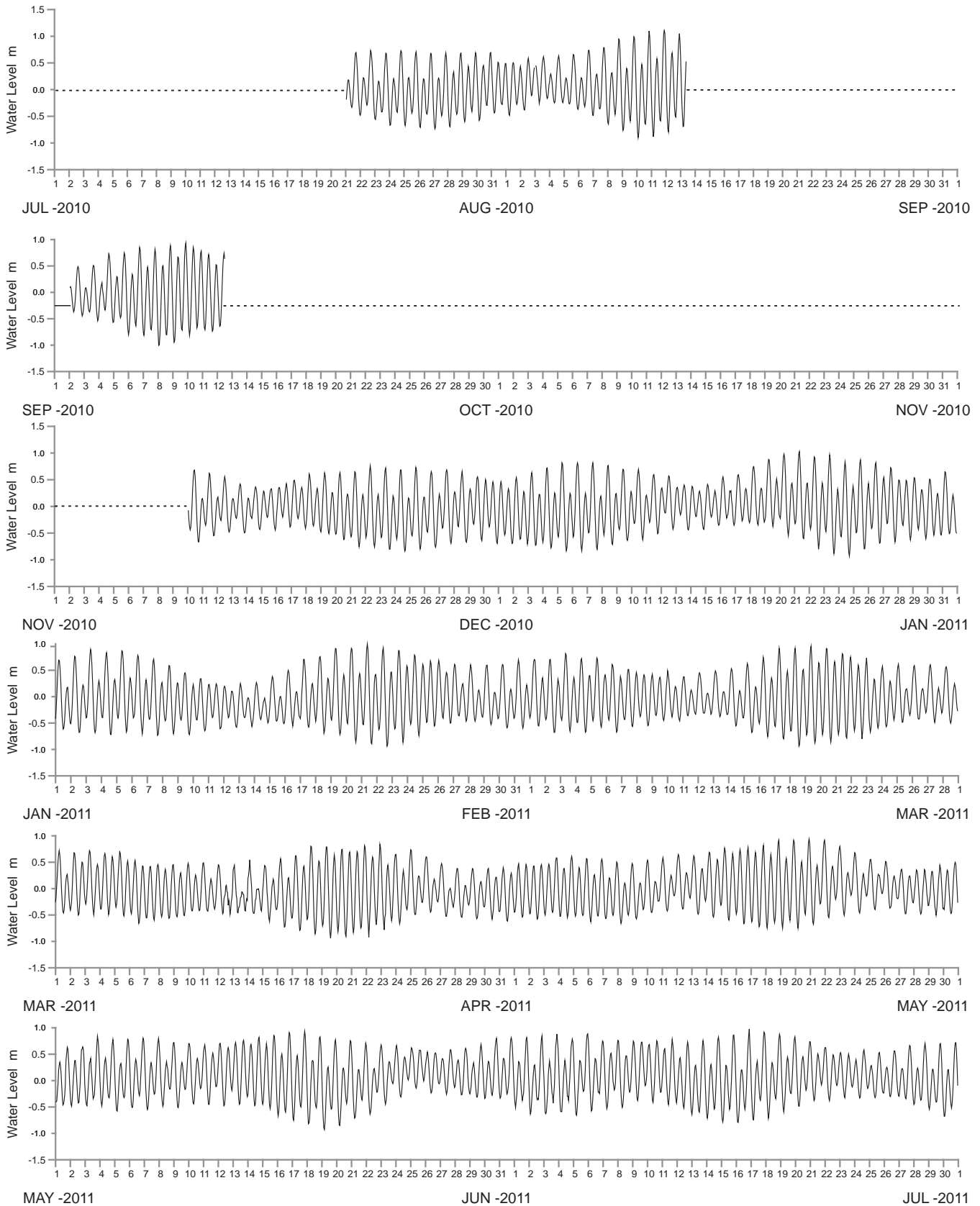
Public Works
 Manly Hydraulics Laboratory

**SHOALHAVEN OFFSHORE
 TIDE GAUGE LOCATION**

MHL
 Report 2158

Figure
51

DRAWING 2158-51.cdr



WATER LEVEL REFERENCED TO MEAN SEA LEVEL

----- DATA LOSS



Public Works
Manly Hydraulics Laboratory

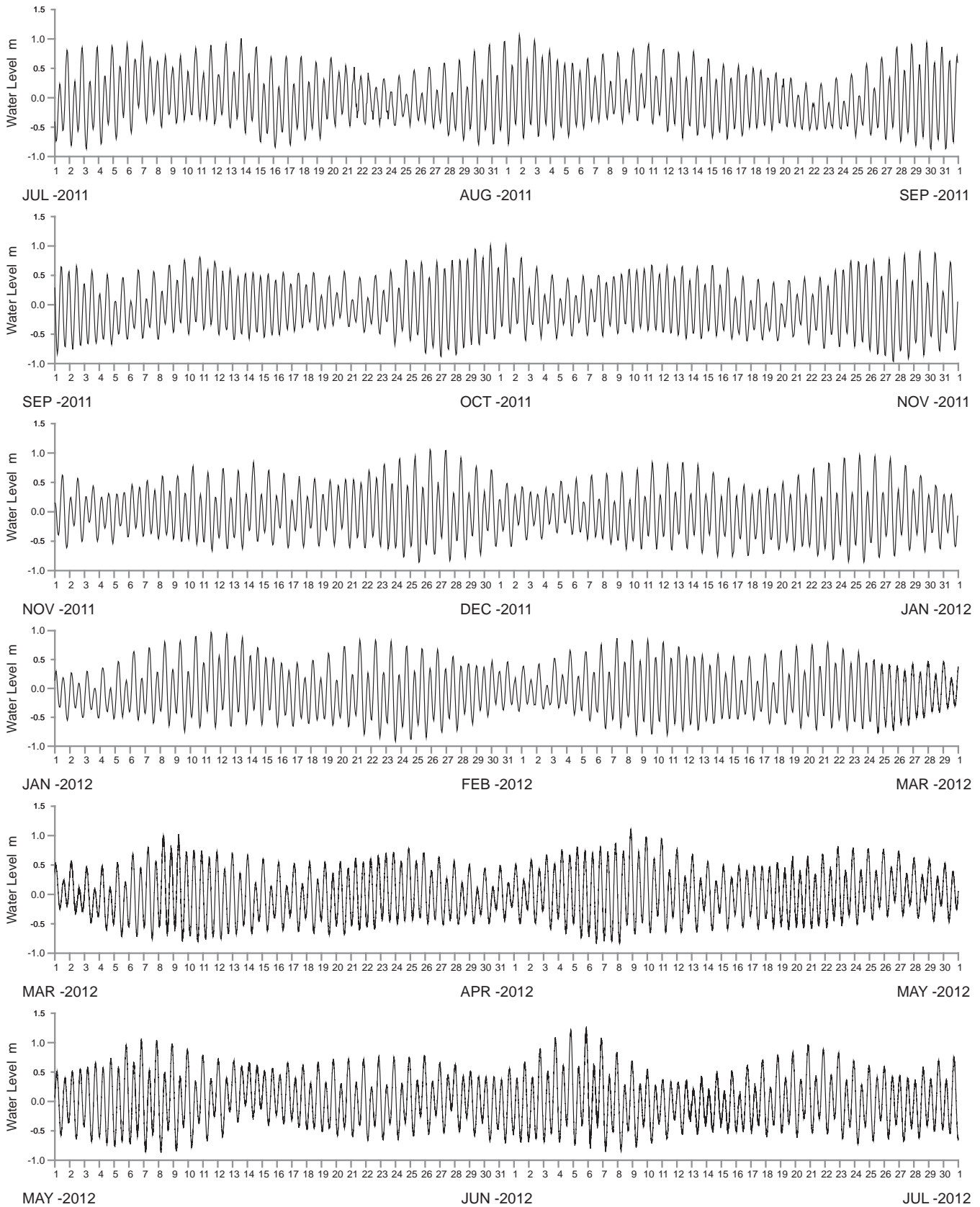
TASMAN SEA AT SHOALHAVEN OFFSHORE
2010-2011

MHL
Report 2158

Figure
52

DRAWING 2158-52

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WATER LEVEL REFERENCED TO MEAN SEA LEVEL



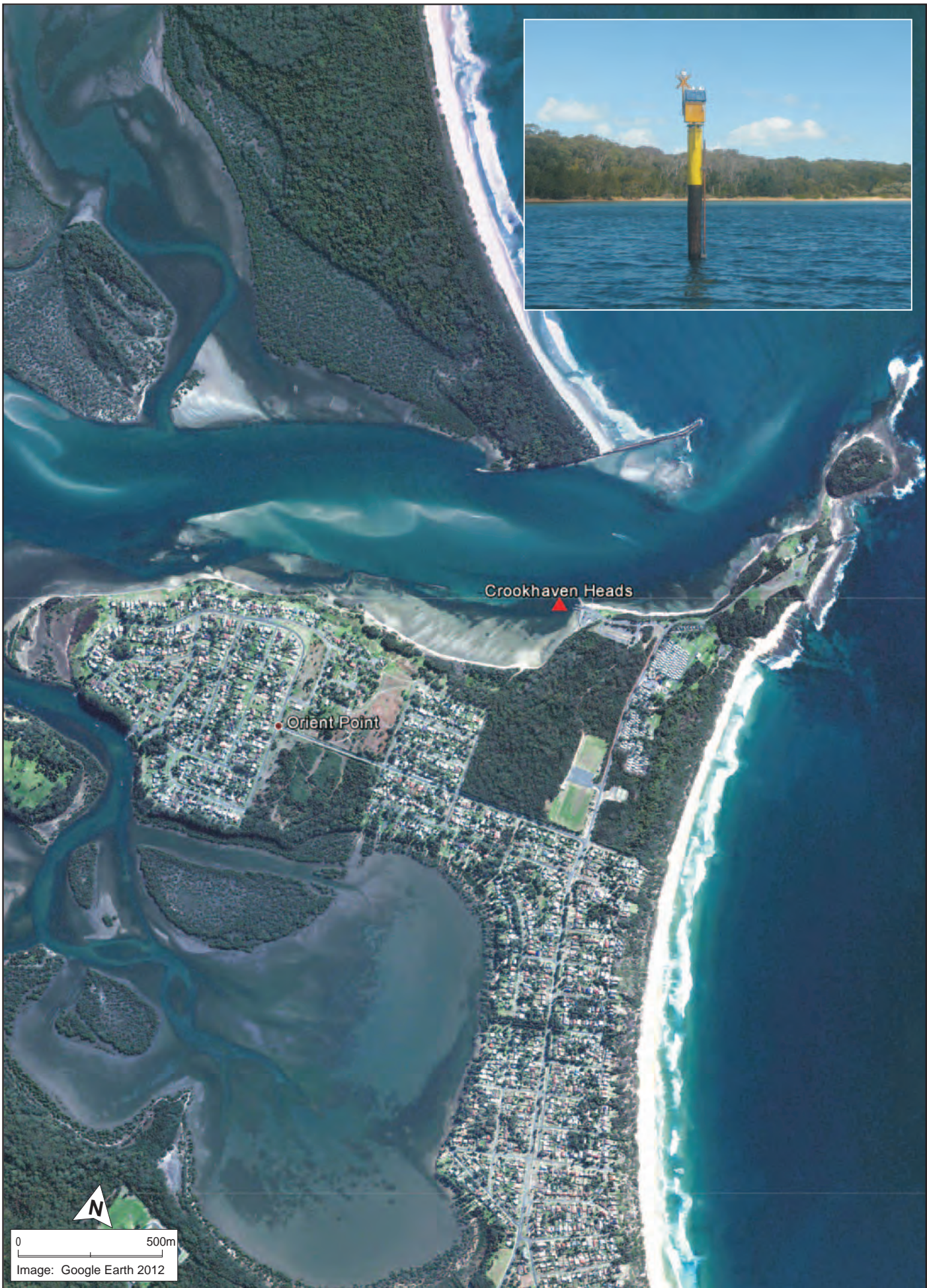
Public Works
Manly Hydraulics Laboratory

TASMAN SEA AT SHOALHAVEN OFFSHORE
2011-2012

MHL
Report 2158

Figure
53

DRAWING 2158-53



Crookhaven Heads

Orient Point



0 500m
Image: Google Earth 2012



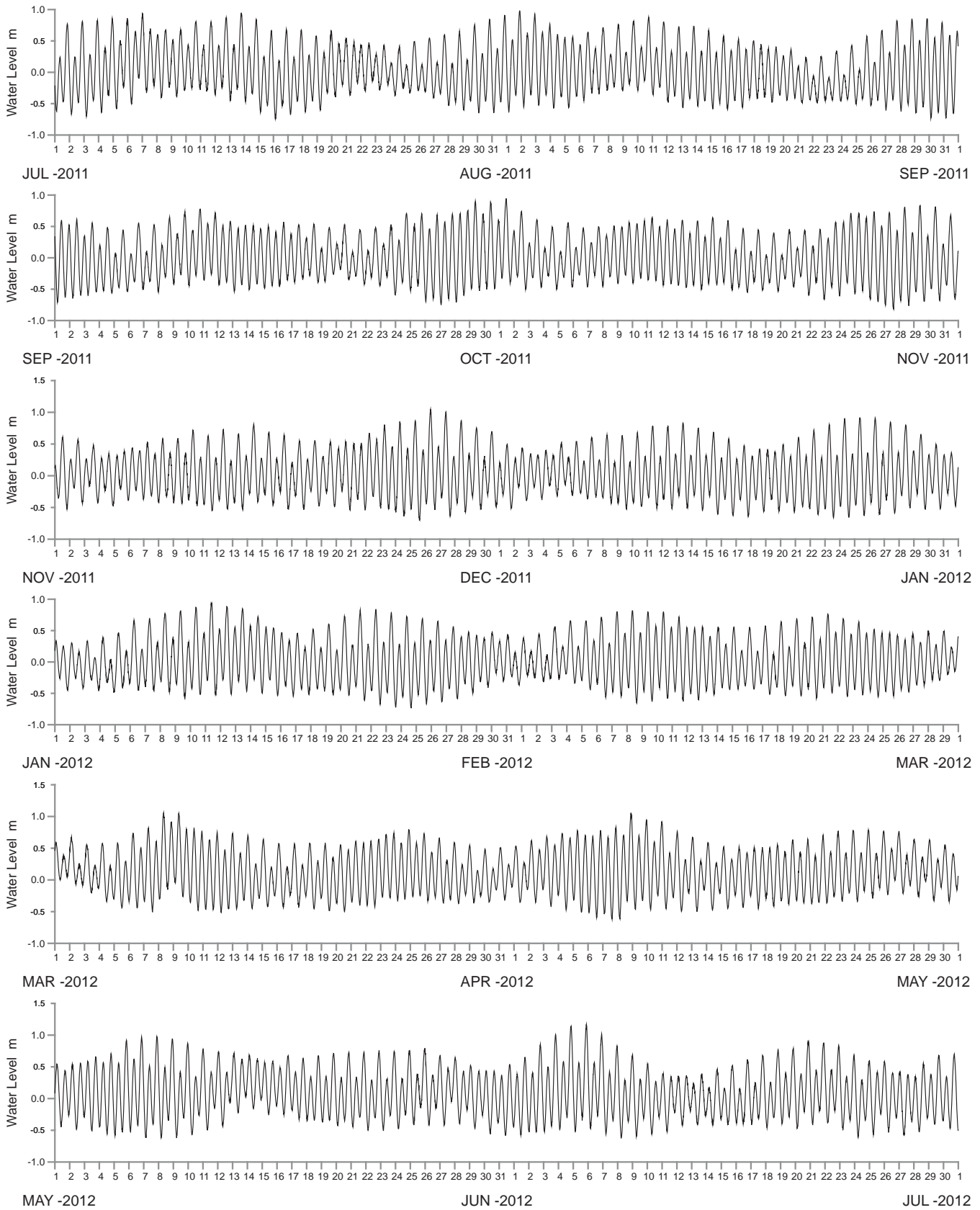
Public Works
Manly Hydraulics Laboratory

**STATION LOCATION
CROOKHAVEN**

MHL
Report 2158

**Figure
54**

DRAWING 2158-54.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM





Jervis Bay



0 250m

Image: Google Earth 2012



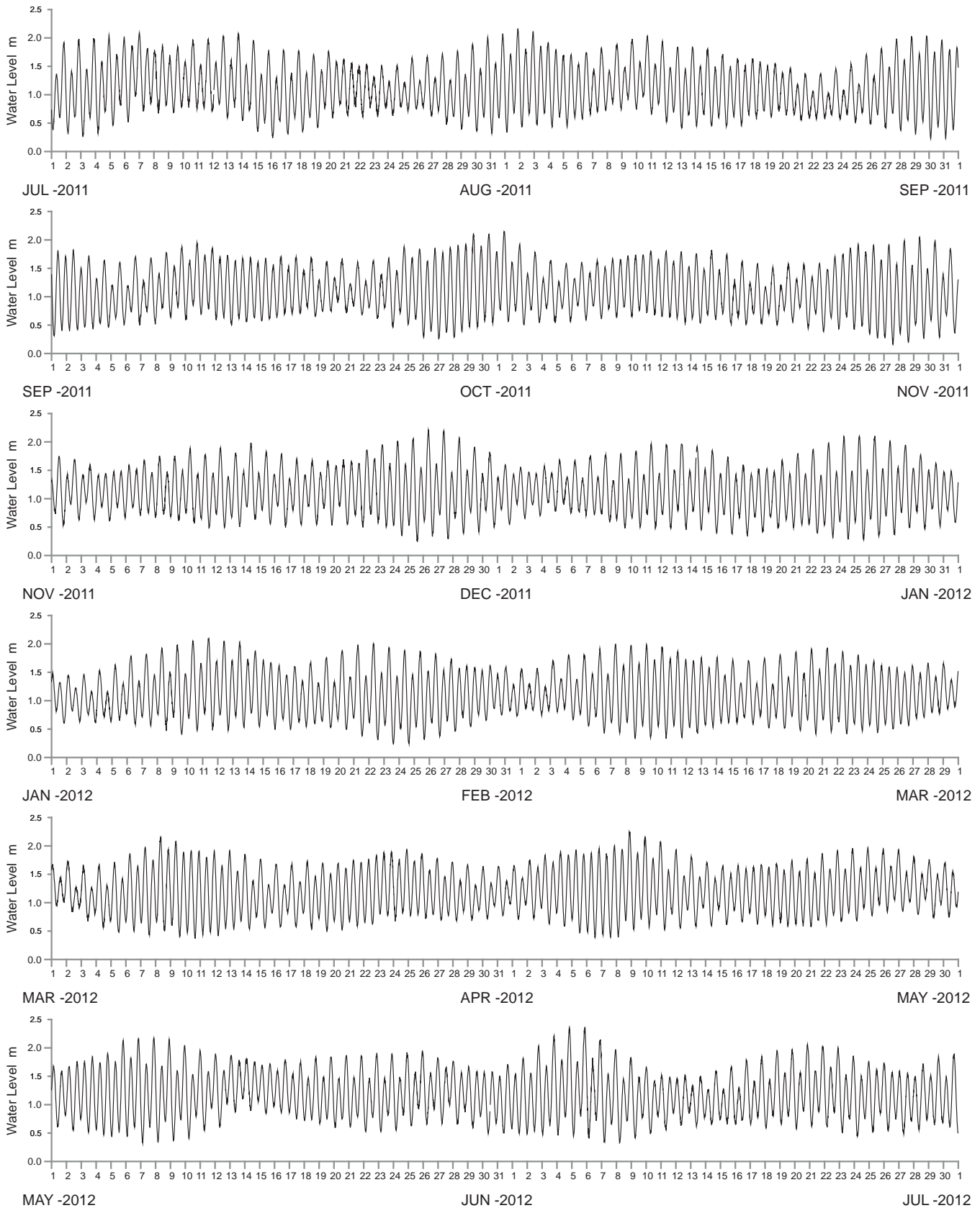
Public Works
Manly Hydraulics Laboratory

STATION LOCATION
JERVIS BAY, HMAS CRESWELL

MHL
Report 2158

Figure
56

DRAWING 2158-56.cdr



WATER LEVEL REFERENCED TO CHART DATUM (JERVIS BAY PORT DATUM)



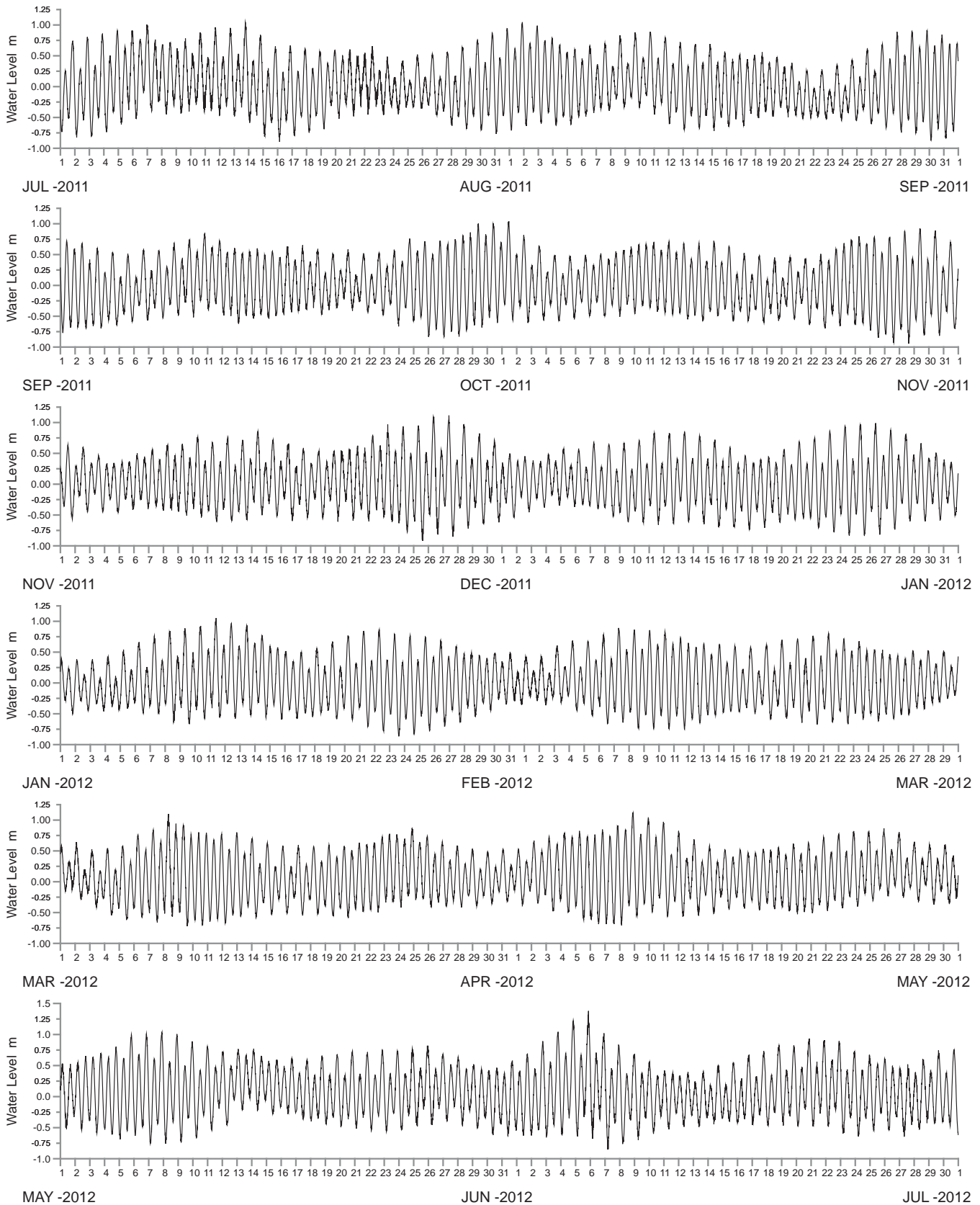


Ulladulla
Ulladulla Harbour



0 500m

Image: Google Earth 2012



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM





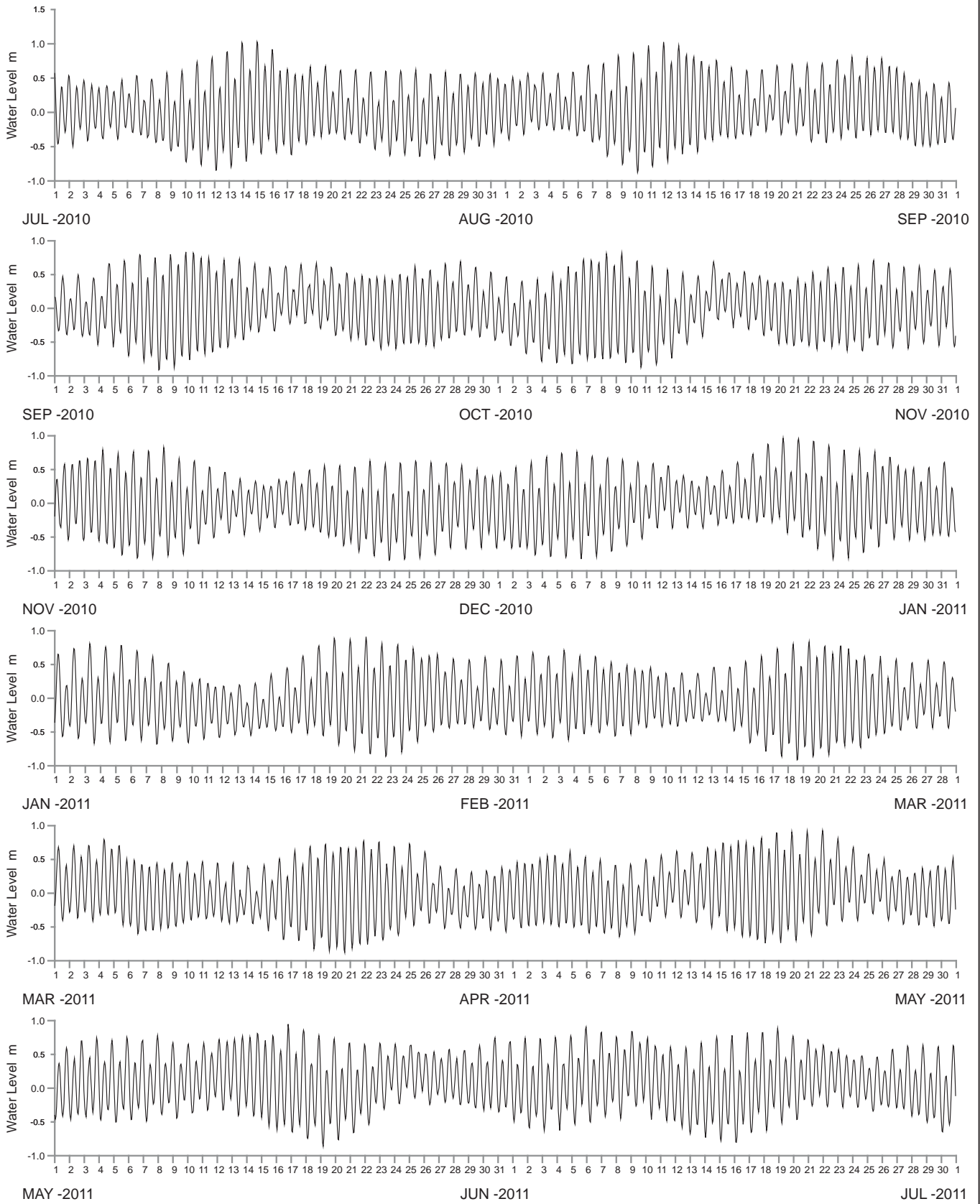
Public Works
Manly Hydraulics Laboratory

**BATEMANS BAY
OFFSHORE TIDE GAUGE LOCATION**

MHL
Report 2158

**Figure
60**

DRAWING 2158-60.cdr



WATER LEVEL REFERENCED TO MEAN SEA LEVEL



Public Works
Manly Hydraulics Laboratory

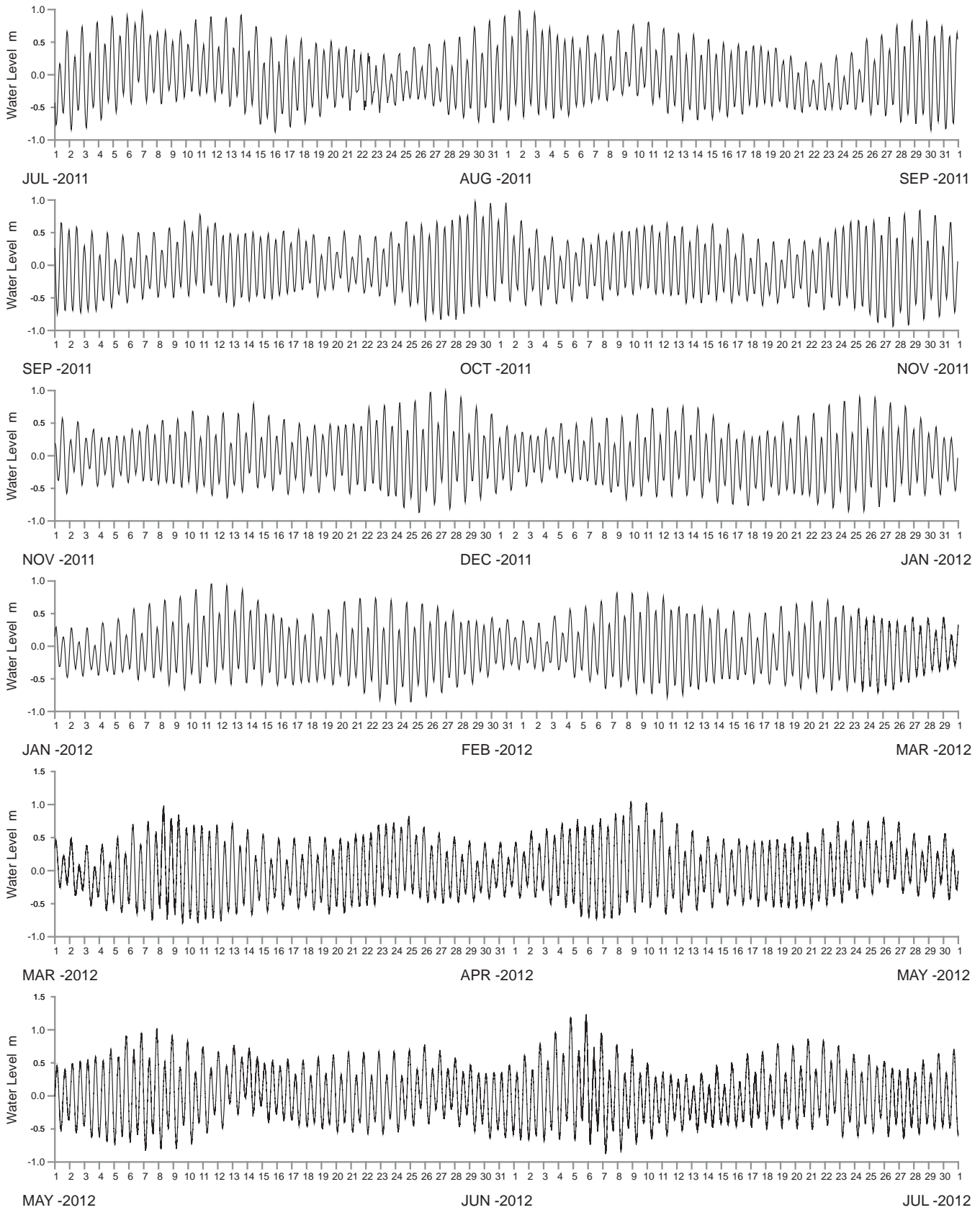
TASMAN SEA AT BATEMANS BAY OFFSHORE
2010-2011

MHL
Report 2158

Figure
61

DRAWING 2158-61

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WATER LEVEL REFERENCED TO MEAN SEA LEVEL



Public Works
Manly Hydraulics Laboratory

TASMAN SEA AT BATEMANS BAY OFFSHORE
2011-2012

MHL
Report 2158

Figure
62

DRAWING 2158-62



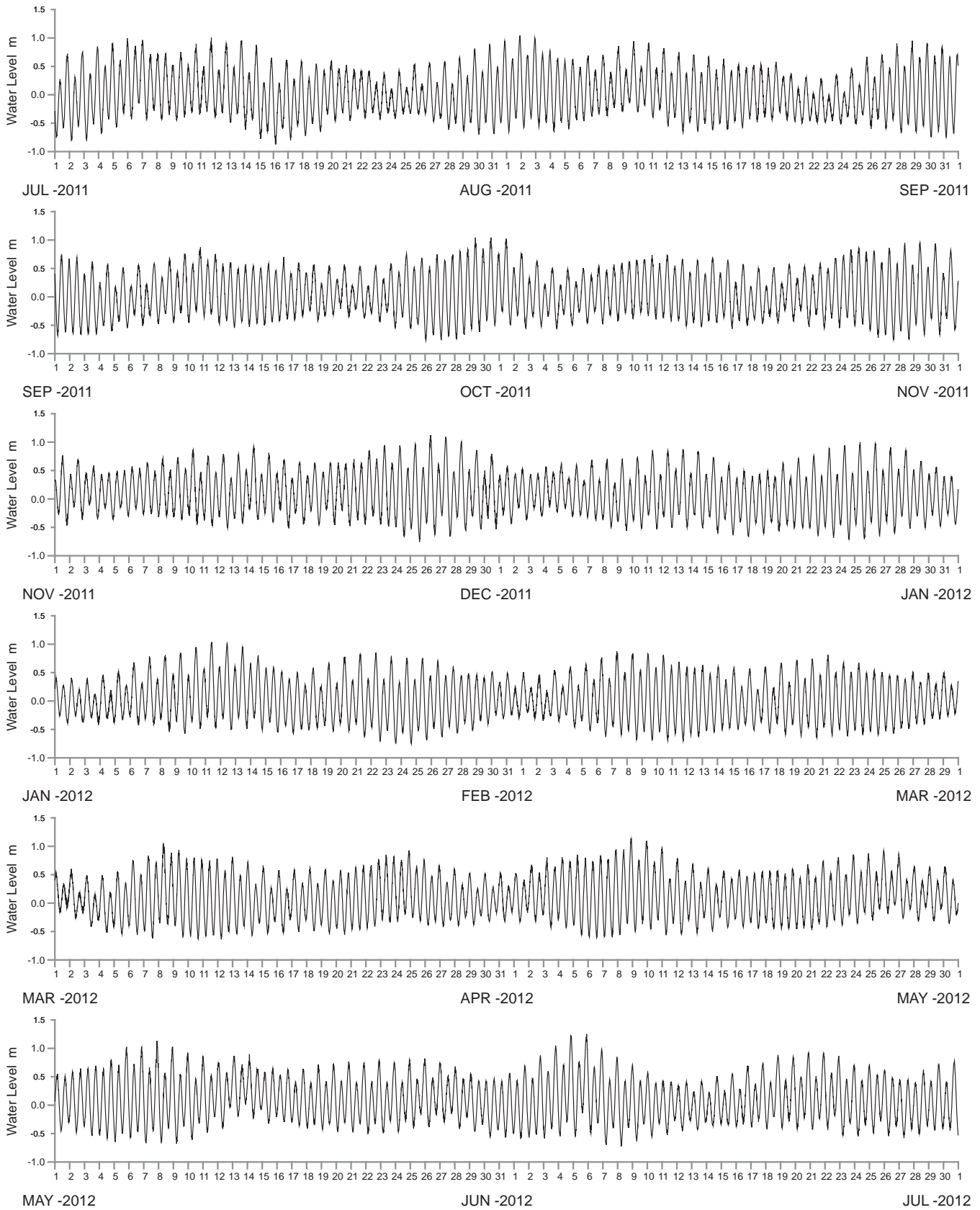
Public Works
Manly Hydraulics Laboratory

STATION LOCATION PRINCESS JETTY

MHL
Report 2158

Figure
63

DRAWING 2158-63.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM



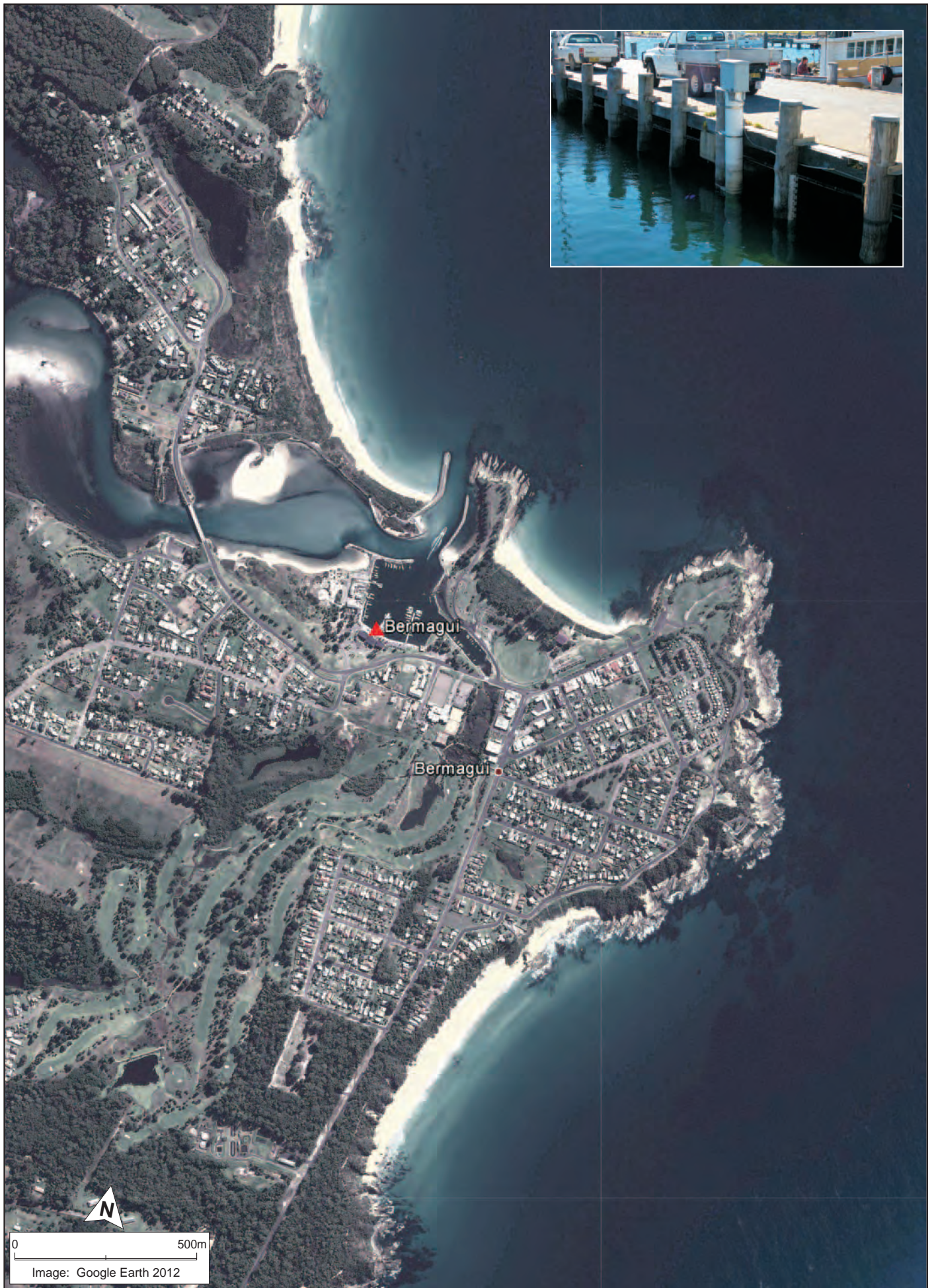
Public Works
Manly Hydraulics Laboratory

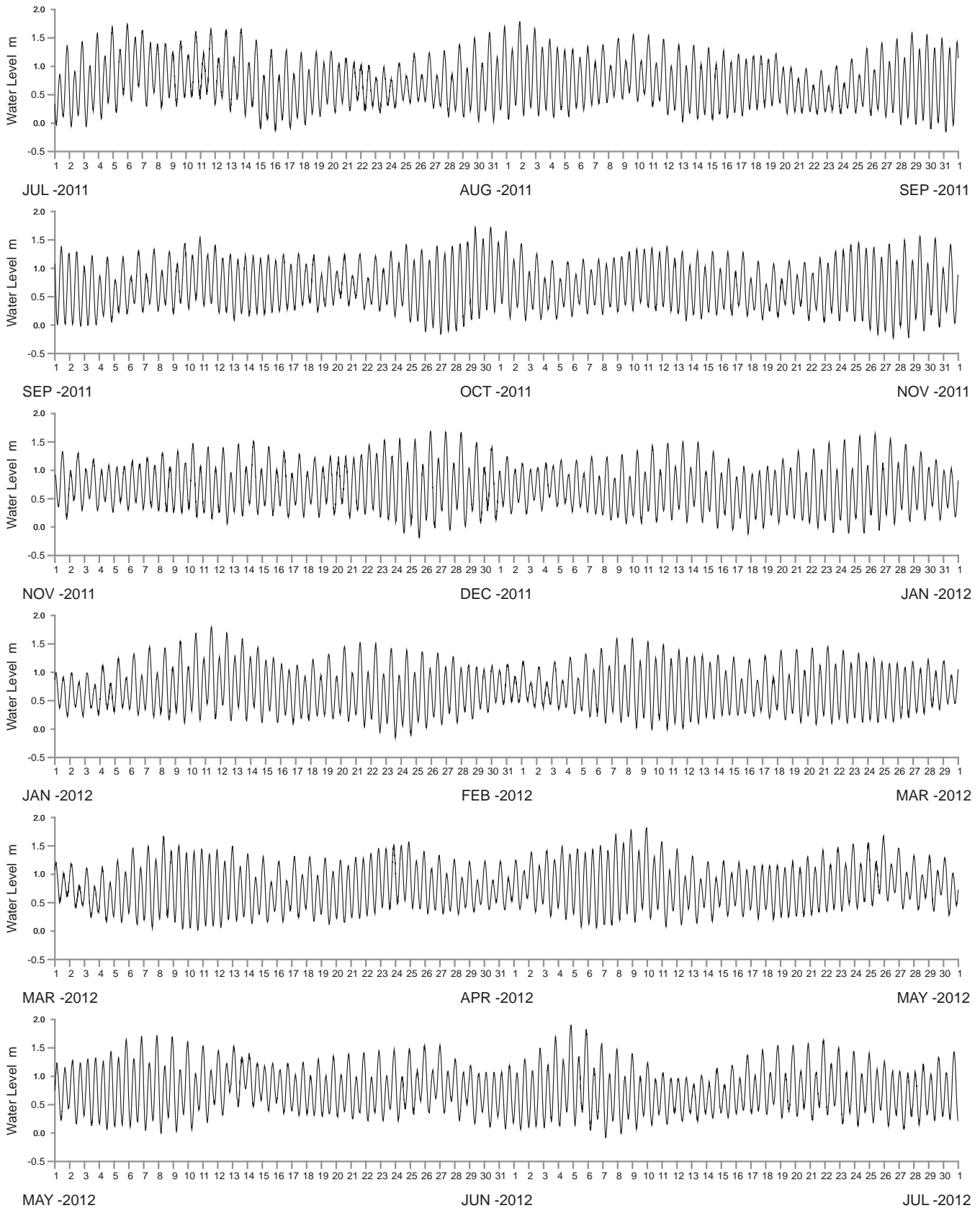
BATEMANS BAY CLYDE RIVER AT PRINCESS JETTY
2011-2012

MHL
Report 2158

Figure
64

DRAWING 2158-64

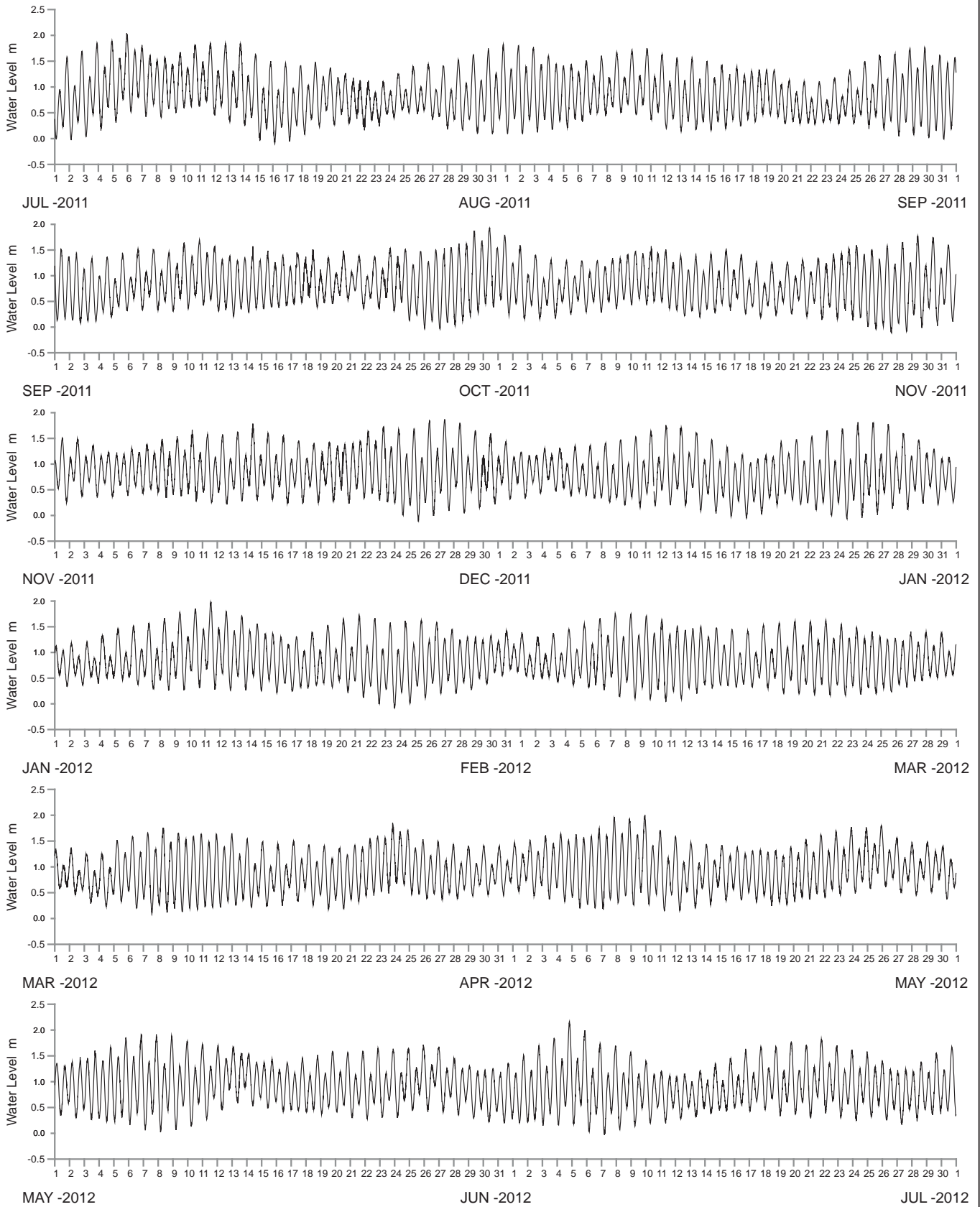




WATER LEVEL REFERENCED TO BERMAGUI LOCAL HYDRO DATUM

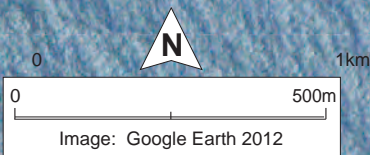






WATER LEVEL REFERENCED TO TWOFOLD BAY HYDRO DATUM





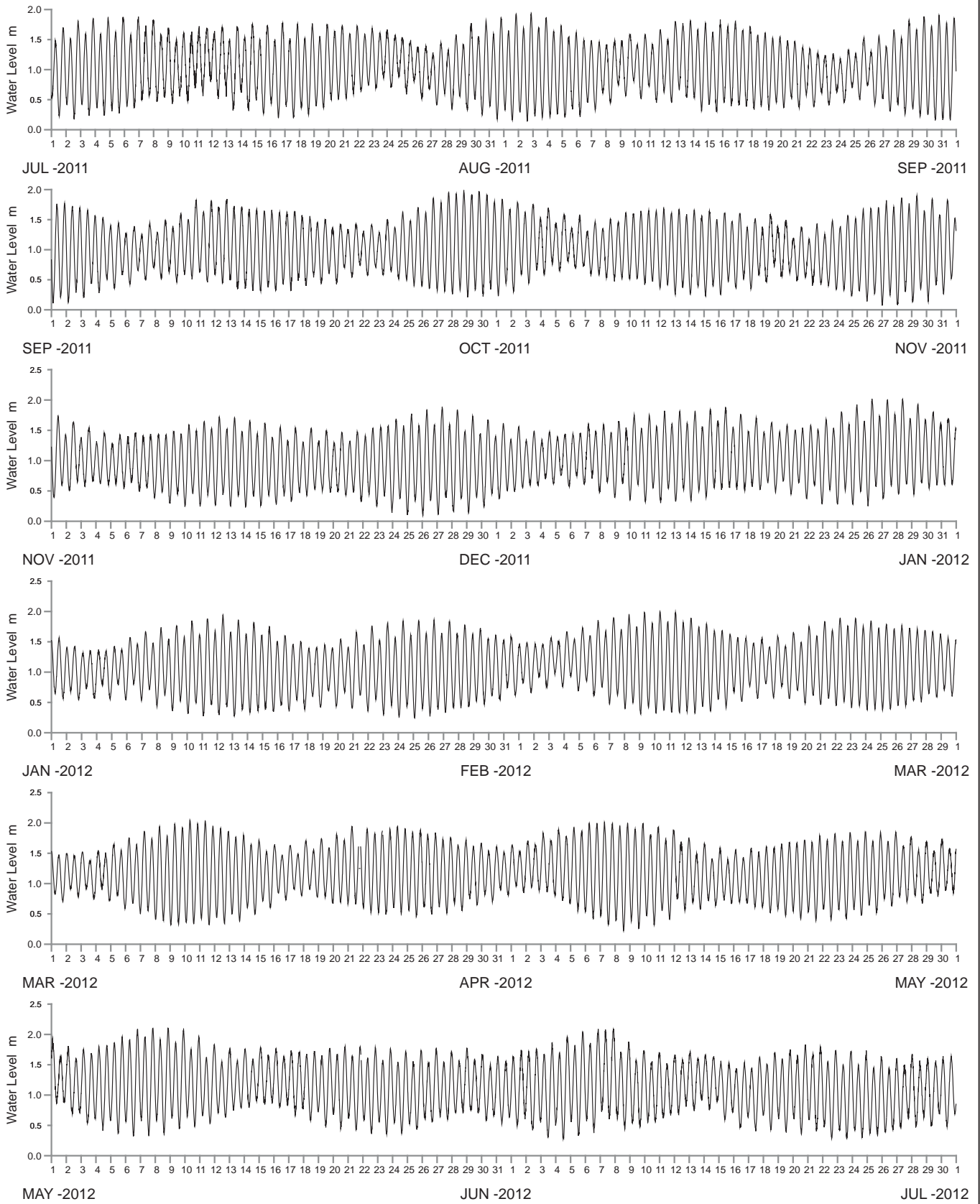
Public Works
Manly Hydraulics Laboratory

STATION LOCATION NORFOLK ISLAND

MHL
Report 2158

Figure
69

DRAWING 2158-69.cdr



WATER LEVEL REFERENCED TO LOWEST ASTRONOMICAL TIDE





Lord Howe Island



0 200m
Image: Google Earth 2012



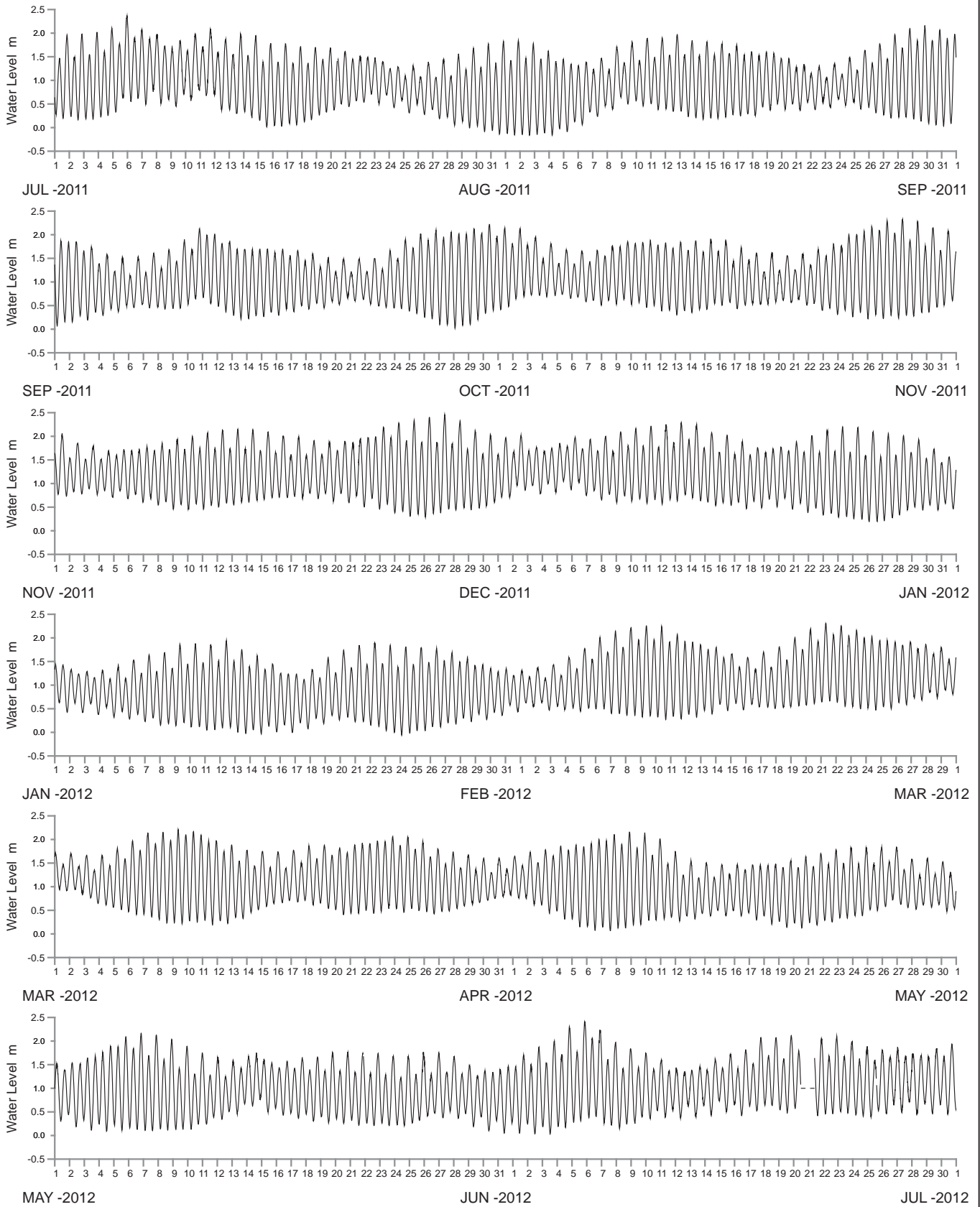
Public Works
Manly Hydraulics Laboratory

STATION LOCATION LORD HOWE ISLAND

MHL
Report 2158

Figure
71

DRAWING 2158-71.cdr



WATER LEVEL REFERENCED TO LORD HOWE ISLAND TIDAL DATUM



Appendix A

Data On-line

Table A1 Current Sites Data On-Line

Coastal Region	Site Name	Location	Period of Data
North	Tweed Regional	Breakwater	Feb 1987 - ongoing
North	Tweed Offshore	Offshore	Dec 1982 - ongoing
North	Brunswick Heads	Breakwater	Mar 1986 - ongoing
North	Ballina	Breakwater	Apr 1986 - ongoing
North	Yamba	Breakwater	Jul 1986 - ongoing
North	Coffs Harbour	Harbour	Jul 1978 - ongoing
Mid North	Port Macquarie	Breakwater	Mar 1986 - ongoing
Mid North	Port Macquarie Offshore	Offshore	Dec 1984 - ongoing
Mid North	Crowdy Head	Harbour	Jul 1986 - ongoing
Mid North	Forster	Breakwater	Jul 1986 - ongoing
Central	Tomaree	Hospital jetty	Oct 1985 - ongoing
Central	Patonga	River	Jun 1992 ongoing
Central	Sydney	Middle Head	Sep 1987 - ongoing
Central	Port Hacking	Hungry Point	Nov 1987 - ongoing
Central	Jervis Bay	HMAS Creswell	Sep 1989 - ongoing
South	Shoalhaven Offshore	Offshore	Sep 2005 - ongoing
South	Princess Jetty	River	Dec 1985 ongoing
South	Batemans Bay Offshore	Snapper Island	Sep 2000 ongoing
South	Bermagui	Working jetty	Mar 1987 - ongoing
South	Eden	Working jetty	Sep 1986 - ongoing
North Tasman Sea	Lord Howe Island	Main wharf	Aug 1994 – ongoing
North Tasman Sea	Norfolk Island	Main jetty	Sep 1994 – ongoing

Appendix B
Historical Tide Data

Table B1 Historical Tide Data

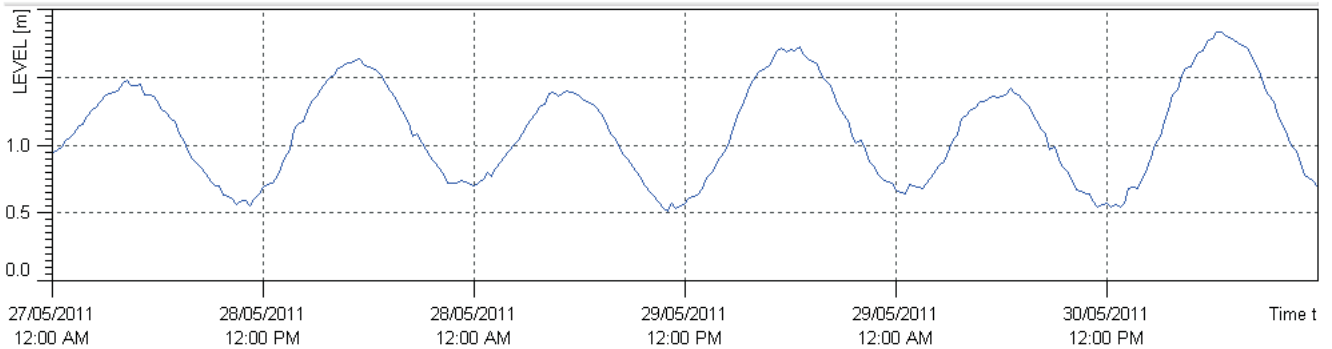
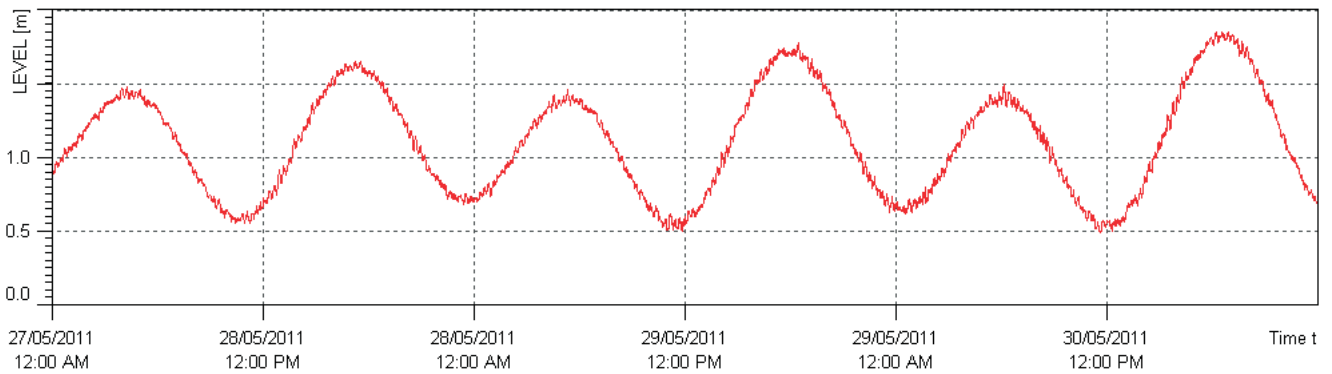
Coastal Region	Site Name	Location	Period of Record
North	Tweed Regional	Breakwater	1914–1916
North	Tweed Regional	Breakwater	Jan 1978–Dec 1978
North	Tweed Regional	Breakwater	Jan 1980–Dec 1980
North	Richmond River	Breakwater	1889–1912
North	Richmond River	Breakwater	1898–1901
North	Richmond River	Breakwater	1901–1905
North	Richmond River	Breakwater	1905–1909
North	Richmond River	Breakwater	1914–1916
North	Richmond River	Ballina	1959–1963
North	Clarence River	Yamba	1900–1924
North	Clarence River	Iluka	1956–1969
North	Clarence River	Breakwater	1900–1904
North	Clarence River	Breakwater	1909–1913
North	Clarence River	Breakwater	1913–1917
North	Clarence River	Breakwater	1914–1916
North	Clarence River	Breakwater	1921–1924
North	Clarence River	Breakwater	Jan 1957–Jun 1957
North	Clarence River	Breakwater	Jun 1957–Dec 1957
North	Clarence River	Breakwater	Dec 1957–May 1958
North	Coffs Harbour	Main harbour	1966–68 and 1969–72
North	Coffs Harbour	Main harbour	Mar 1972–May 1972
North	Coffs Harbour	Main harbour	Sep 1972–Feb 1973
North	Coffs Harbour	Main harbour	Jan 1961–Dec 1964
North	Coffs Harbour	Main harbour	Jul 1952–Dec 1952
North	Coffs Harbour	Main harbour	Aug 1951–Feb 1952
North	Coffs Harbour	Main harbour	1953–1960
North	Bellinger/Kalang River	Entrance	1914–1916
North	Macleay River	Entrance	1901–1905
North	Macleay River	Entrance	1902–1903
North	Macleay River	Entrance	1905–1909
North	Macleay River	Entrance	1909–1913
North	Macleay River	Entrance	1914–1916
Mid North	Hastings River	Breakwater	1914–1916
Mid North	Camden Haven River	Breakwater	1914–1916
Mid North	Manning River	Breakwater	1914–1916
Mid North	Forster	Breakwater	1914–1916
Central	Newcastle	Boat Harbour	1899–1921
Central	Newcastle	Breakwater	1889–1902

Coastal Region	Site Name	Location	Period of Record
Central	Newcastle	Breakwater	1903–1907
Central	Newcastle	Breakwater	1903–1904
Central	Newcastle	Breakwater	1907–1911
Central	Newcastle	Breakwater	1909–1913
Central	Newcastle	Breakwater	1915–1921
Central	Port Jackson	Fort Denison	1956–1959
Central	Port Kembla		1957–1960
Central	Port Kembla		1961–1965
Central	Crookhaven River	Entrance	1914–1916
Central	Jervis Bay	HMAS Creswell	1914–1919
Central	Jervis Bay	Huskisson	1987–1989
South	Batemans Bay Offshore	Snapper Island	1986–1990
South	Moruya River	Entrance	1914–1916
South	Moruya River	Entrance	1951–1952
South	Moruya River	Entrance	Mar 1952–Aug 1952
South	Moruya River	Entrance	Aug 1952–Sep 1952
South	Eden	Snug Cove	1954–1956

Fort Denison data courtesy of Sydney Ports Corporation and BoM National Tidal Centre.

Appendix C
Sample Outputs

Coffs Harbour 1-minute data



Coffs Harbour 15-minute data



Station Name, Port Stephens (Live),,
Station Number,209471,,
Latitude,+152:10:56.06,,
Longitude,-32:42:53.57,,
Datum,PSHD,,

'''
date,time,value,value.status
5/07/2011,0:00:00,1.61325,6 (Good)
5/07/2011,0:15:00,1.56495,6 (Good)
5/07/2011,0:30:00,1.47403,6 (Good)
5/07/2011,0:45:00,1.39316,6 (Good)
5/07/2011,1:00:00,1.3186,6 (Good)
5/07/2011,1:15:00,1.22369,6 (Good)
5/07/2011,1:30:00,1.10246,6 (Good)
5/07/2011,1:45:00,1.03073,6 (Good)
5/07/2011,2:00:00,0.949726,6 (Good)
5/07/2011,2:15:00,0.84358,6 (Good)
5/07/2011,2:30:00,0.756913,6 (Good)
5/07/2011,2:45:00,0.658031,6 (Good)
5/07/2011,3:00:00,0.573691,6 (Good)
5/07/2011,3:15:00,0.504744,6 (Good)
5/07/2011,3:30:00,0.423529,6 (Good)
5/07/2011,3:45:00,0.361451,6 (Good)
5/07/2011,4:00:00,0.317804,6 (Good)
5/07/2011,4:15:00,0.276461,6 (Good)
5/07/2011,4:30:00,0.214138,6 (Good)
5/07/2011,4:45:00,0.196576,6 (Good)
5/07/2011,5:00:00,0.182245,6 (Good)
5/07/2011,5:15:00,0.190659,6 (Good)
5/07/2011,5:30:00,0.205091,6 (Good)
5/07/2011,5:45:00,0.22192,6 (Good)
5/07/2011,6:00:00,0.237748,6 (Good)
5/07/2011,6:15:00,0.291828,6 (Good)
5/07/2011,6:30:00,0.337178,6 (Good)
5/07/2011,6:45:00,0.395157,6 (Good)
5/07/2011,7:00:00,0.441683,6 (Good)
5/07/2011,7:15:00,0.495641,6 (Good)



*****NSW PUBLIC WORKS, MANLY HYDRAULICS LABORATORY*****

110B KING STREET, MANLY VALE N.S.W. 2093, AUSTRALIA. TELEPHONE (02)9949 0200

ANALYSIS OF TIDAL OBSERVATIONS

TIME OF ANALYSIS : 1555:20/12/2006
ANALYSIS PERFORMED BY : ES using INTERACTIVE program MTIDE1DBX V1.0
STATION LOCATION : EDEN, N.S.W., AUSTRALIA
STATION NAME : BOAT HARBOUR
STATION LATITUDE : 037 DEG 04 MIN SOUTH
STATION LONGITUDE : 149 DEG 54 MIN EAST
DATUM : TWOFOLD BAY HYDRO DATUM
ANALYSIS PERIOD START TIME : 0000:01/07/2005
ANALYSIS PERIOD FINISH TIME : 2300:01/07/2006
MID POINT TIME : 2300:30/12/2005
PERIOD OF ANALYSIS : 366 DAYS 00 HRS
LOCAL TIME ZONE NAME : EASTERN STANDARD TIME
LOCAL TIME FACTOR : GMT +10.00 HRS
TIME MERIDIAN : -9.99 HRS

TIDAL PLANES IN METRES ABOVE ZERO OF LOCAL GAUGE VALUES

High High Water (Solstices Springs)	H.H.W.(S.S.)	:	1.823
Mean High Water Springs	M.H.W.S.	:	1.423
Mean High Water	M.H.W.	:	1.320
Mean High Water Neaps	M.H.W.N.	:	1.216
Mean Sea Level	M.S.L.	:	0.856
Mean Low Water Neaps	M.L.W.N.	:	0.495
Mean Low Water	M.L.W.	:	0.392
Mean Low water Springs	M.L.W.S.	:	0.288
Indian Spring Low Water	I.S.L.W.	:	0.003

TIDAL RANGES IN METRES

Mean Spring Range	(M.H.W.S. - M.L.W.S.)	:	1.135
Mean Neap Range	(M.H.W.N. - M.L.W.N.)	:	0.721
Mean Range	(M.H.W. - M.L.W.)	:	0.928
Range	(H.H.W.(S.S.) - I.S.L.W.)	:	1.821

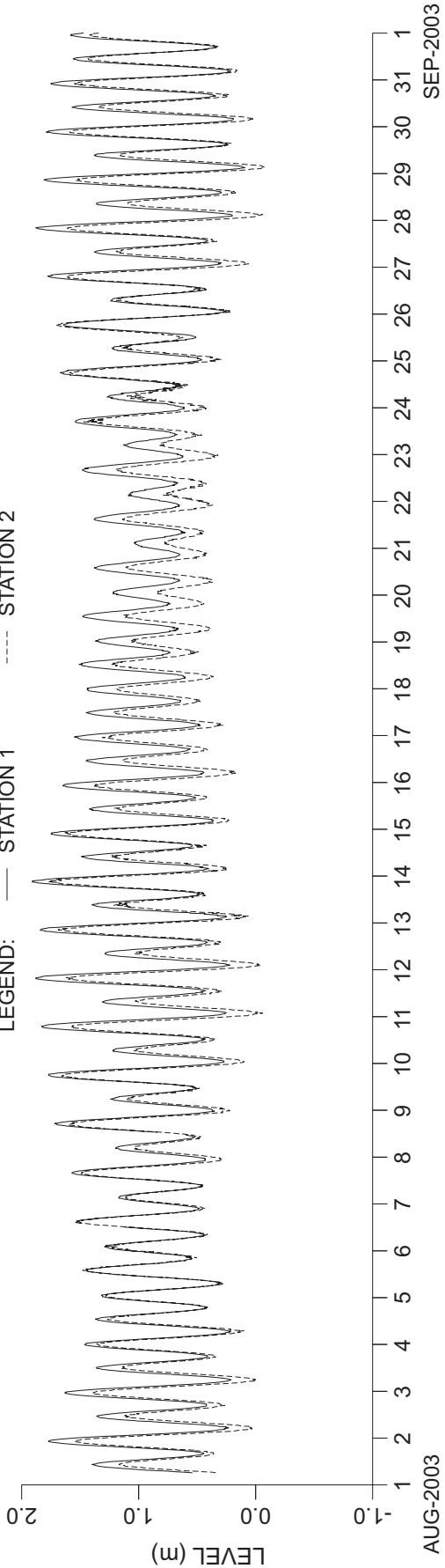




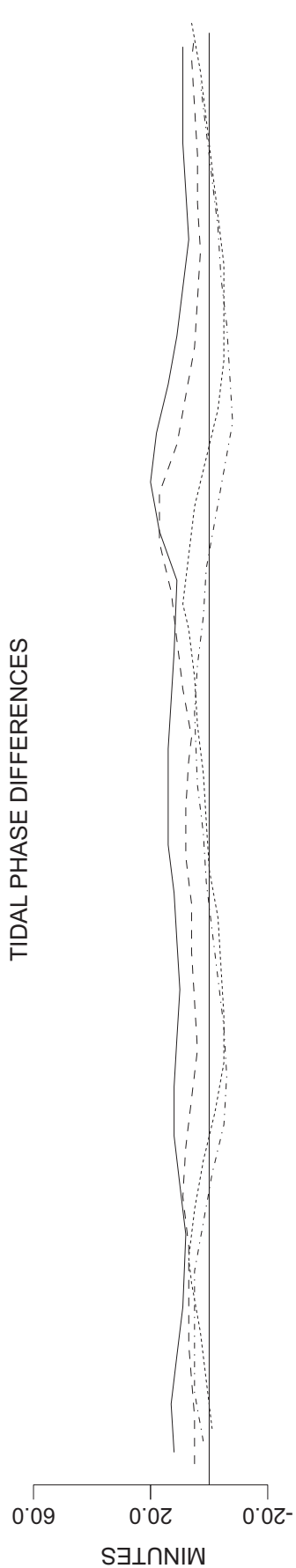
TIDAL PHASE DIFFERENCES BETWEEN SYDNEY AND EDEN

STATION 1: SYDNEY STATION 2: EDEN WHARF TIDE No.2

LEGEND: — STATION 1 - - - STATION 2



TIDAL PHASE DIFFERENCES



LEGEND:

—	HIGH TIDE ENVELOPE HIGH BOUNDARY	: MEAN=	11.7	STD DEVIATION=	3.0	MIN=	7	MAX=	20
.....	HIGH TIDE ENVELOPE LOW BOUNDARY	: MEAN=	1.1	STD DEVIATION=	4.2	MIN=	-5	MAX=	9
- . - .	LOW TIDE ENVELOPE LOW BOUNDARY	: MEAN=	-0.3	STD DEVIATION=	4.1	MIN=	-8	MAX=	5
- - -	LOW TIDE ENVELOPE HIGH BOUNDARY	: MEAN=	7.3	STD DEVIATION=	3.4	MIN=	3	MAX=	17
	ALL ABOVE	: MEAN=	4.9	STD DEVIATION=	6.1	MIN=	-8	MAX=	20

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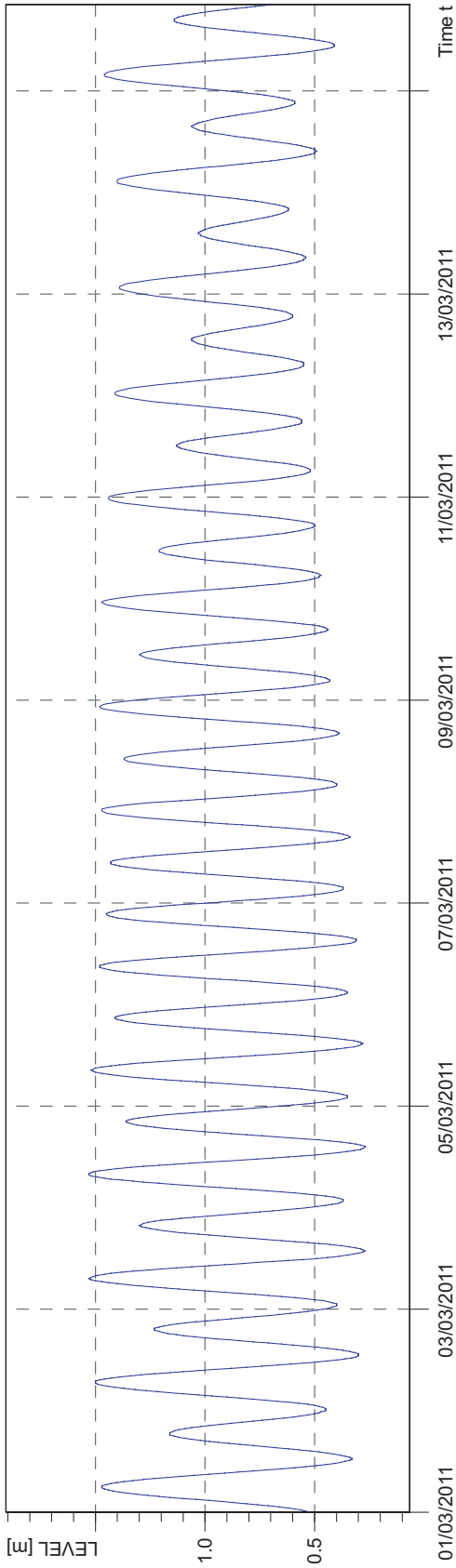
TIDAL LEVEL STATISTICS

=====

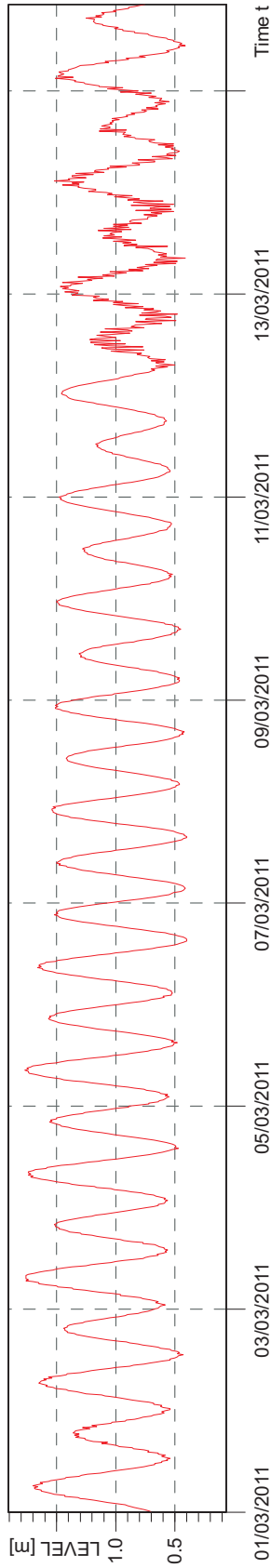
STATION NAME : SYDNEY TIDE GAUGE
 RECORDER TYPE : DATATAKER
 LATITUDE/LONGITUDE : 33-50 DEG. SOUTH, 151-15 DEG. EAST
 DATA START : 01-JUL-2005
 DATA FINISH : 30-JUN-2006
 TOTAL YEARS OF DATA : 1.00
 DATABASE TIME INTERVAL (min) : 60
 THRESHOLD LEVEL (m) : 1.93
 DATUM : ZERO CAMP COVE
 DATE OF ISSUE : 1617:20/12/2006
 ANALYSIS PERFORMED BY : ES using INTERACTIVE program WDBRNKX V1.0
 COMMENTS : Recorded levels.

RANK	PEAK (m)	DATE	TIME	START	DURATION (hr)	MAX RISE (cm/hr)	PERIOD (yr)
1	2.21	28-APR-2006	20:00	28-APR-2006	2.0	4.0	2.0
2	2.11	27-APR-2006	20:00	27-APR-2006	N/A	N/A	1.0
3	2.08	03-JAN-2006	11:00	03-JAN-2006	3.0	16.0	0.7
4	2.06	20-AUG-2005	21:00	20-AUG-2005	2.0	5.0	0.5
5	2.05	02-JAN-2006	10:00	02-JAN-2006	2.0	4.0	0.4
6	2.04	19-AUG-2005	20:00	19-AUG-2005	2.0	10.0	0.3
7	2.04	13-DEC-2005	06:00	13-DEC-2005	2.0	12.0	0.3
8	2.04	17-DEC-2005	09:00	17-DEC-2005	2.0	9.0	0.2
9	2.04	01-FEB-2006	10:00	01-FEB-2006	2.0	14.0	0.2
10	2.03	18-DEC-2005	10:00	18-DEC-2005	2.0	2.0	0.2
11	2.02	01-JAN-2006	09:00	01-JAN-2006	2.0	5.0	0.2
12	2.02	31-JAN-2006	09:00	31-JAN-2006	1.0	N/A	0.2
13	2.02	29-APR-2006	21:00	29-APR-2006	1.0	N/A	0.2
14	2.00	16-SEP-2005	19:00	16-SEP-2005	1.0	6.0	0.1
15	2.00	30-JAN-2006	09:00	30-JAN-2006	1.0	3.0	0.1
16	1.98	28-FEB-2006	08:00	28-FEB-2006	1.0	N/A	0.1
17	1.97	21-AUG-2005	22:00	21-AUG-2005	1.0	1.0	0.1
18	1.96	17-SEP-2005	20:00	17-SEP-2005	1.0	3.0	0.1
19	1.96	29-JAN-2006	08:00	29-JAN-2006	1.0	3.0	0.1
20	1.95	01-MAR-2006	09:00	01-MAR-2006	0.0	N/A	0.1
21	1.95	30-APR-2006	22:00	30-APR-2006	1.0	N/A	0.1
22	1.94	21-JUL-2005	20:00	21-JUL-2005	0.0	N/A	0.1
23	1.94	24-JUL-2005	23:00	24-JUL-2005	1.0	4.0	0.1
24	1.94	15-NOV-2005	07:00	15-NOV-2005	1.0	N/A	0.1
25	1.94	16-NOV-2005	08:00	16-NOV-2005	N/A	N/A	0.1
26	1.94	03-DEC-2005	09:00	03-DEC-2005	N/A	N/A	0.1
27	1.94	05-DEC-2005	11:00	05-DEC-2005	1.0	2.0	0.1
28	1.94	14-DEC-2005	07:00	14-DEC-2005	1.0	6.0	0.1
29	1.94	16-DEC-2005	08:00	16-DEC-2005	1.0	N/A	0.1
30	1.94	23-APR-2006	04:00	23-APR-2006	1.0	5.0	0.1
31	1.94	25-APR-2006	06:00	25-APR-2006	N/A	N/A	0.1
32	1.93	22-JUL-2005	21:00	22-JUL-2005	N/A	N/A	0.1
33	1.93	08-OCT-2005	11:00	08-OCT-2005	0.0	N/A	0.1
34	1.93	31-DEC-2005	08:00	31-DEC-2005	N/A	N/A	0.1
35	1.93	16-APR-2006	22:00	16-APR-2006	1.0	5.0	0.1
36	1.93	24-MAY-2006	17:00	24-MAY-2006	0.0	N/A	0.1

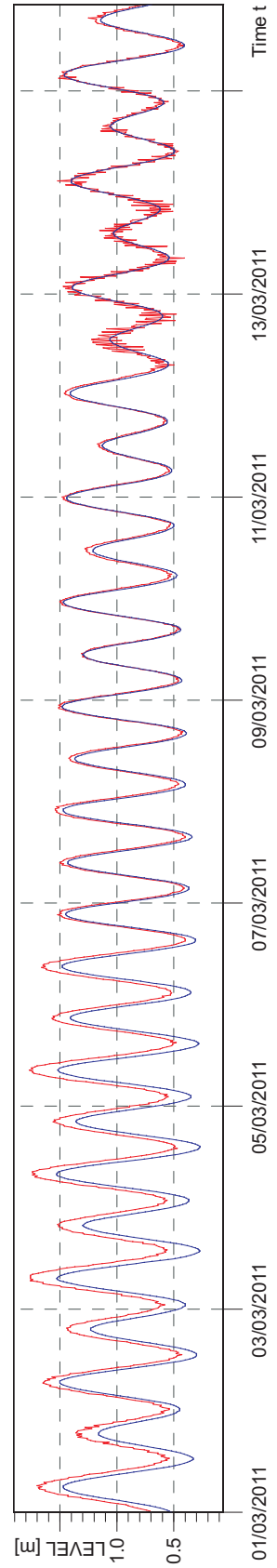




Predicted Data



Measured Data



Appendix D
Glossary of Terms

Glossary of Terms

Amplitude (H)	One-half the range of a constituent tide. By analogy, it may be applied also to the maximum speed of a constituent current.
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 $y = A \cos (at + \acute{a})$, 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 $(at + \acute{a})$ 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
Encoder	A device that translates tidal movement into computer readable data.
Ellipsoid	an idealised model representing the mean sea level of the earth and is used as a computational reference for global position fixing
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 runoff 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_1 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_1 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 will 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 = $T + h = 15.041,068,6^\circ$ per solar hour.
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 = $2T - s + p = 29.455,625,3^\circ$ 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_1 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_1 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 = $2T - 2s + 2h = 28.984,104,2^\circ$ 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.
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 = $T - 2s + h = 13.943,035,6^\circ$ per solar hour.
Phase	<ol style="list-style-type: none"> 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 = $2T = 30.000,000,0^\circ$ 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) = $2L / \text{square root}(gd)$ 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	<ol style="list-style-type: none"> 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 and mean low water springs
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.
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 E
Publications of Interest

Publications of Interest

Data Reports

MHL Annual Ocean Tide Levels Summaries available from 1986-87 to 2010-11.

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).

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 2004, *Tidal Data Compilation 2002*, MHL Report 1200, May 2004.

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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.

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, *OEHS NSW Tidal Planes Analysis: 1990-2010 Harmonic Analysis*, MHL Report 2053, October 2012.

Mean Sea Level

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*.

National Mapping Council, Permanent Committee on Tides and Mean Sea Level (PCTMSL), *Tide Gauge Survey Information*.

Anomalies and Storm Surge Analysis

Manly Hydraulics Laboratory 1991, *Storm Surges Monitored Along the NSW Coast March-April 1990*, Report No. MHL591.

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Public Works
Manly Hydraulics Laboratory

110B King Street
Manly Vale NSW 2093
T 02 9949 0200
F 02 9948 6185
TTY 1300 301 181
www.mhl.nsw.gov.au