DIPNR
MERIMBULA LAKE, PAMBULA LAKE AND BACK LAGOON
TIDAL DATA COLLECTION
September-November 2003

MHL Report No. 1290

NSW Department of Commerce
Manly Hydraulics Laboratory

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Foreword

The data presented in this report was collected in Merimbula Lake, Pambula Lake and Back Lagoon estuaries between 22 September and 28 November 2003 as part of the NSW Department of Infrastructure Planning and Natural Resources' (DIPNR) Estuary Management Program. The data obtained will be used to assist in the implementation of the existing Estuary Management Plan for Merimbula Lake and Back Lagoon and in the preparation of the proposed Estuary Management Plan for Pambula Lake.

A full set of the raw data collected in the field and calculations used in the preparation of this report are retained at Manly Hydraulics Laboratory (MHL) and may be viewed upon application to the Environmental Data Services Manager. Work notes are stored in MHL archive file no. 1254.

This report was prepared by Mr D Allsop and Mr R Kadluczka.

Executive Summary

The three estuaries, Merimbula Lake, Pambula Lake and Back Lagoon, are located within a few kilometres of each other on the NSW south coast approximately 360 km south of Sydney. All three are small-sized estuaries with only a few tributaries. Merimbula Lake has Boggy and Bald Hills creeks; Pambula Lake has the Pambula and Yowaka rivers; and Back Lagoon has Merimbula Creek. Merimbula Lake is important for oyster farming and Pambula Lake has some commercial fishing, prawning and oyster farming. Back Lagoon is the smallest of the three and supports no commercial activities.

The town of Merimbula is located to the north of Merimbula Lake, to the west and south of Back Lagoon. The settlement of Pambula Beach is located 6 km south on the north side of the entrance to Pambula Lake. The entrances to both Merimbula and Pambula lakes are open and untrained. The entrance to Back Lagoon is generally closed and untrained. The northern part of Ben Boyd National Park is located in the catchment of Pambula Lake.

An Estuary Management Plan has been prepared by the Bega Valley Council's Estuary Management Committee for Merimbula Lake and Back Lagoon. The plan endeavours to balance the environmental needs of each estuary with the competing pressures from recreational, residential and commercial development. An Estuary Management Plan has yet to be prepared for Pambula Lake. As part of the Department of Infrastructure Planning and Natural Resources' Estuary Management Program, Manly Hydraulics Laboratory was commissioned to undertake a data collection exercise in the three estuaries. The aim of this data collection exercise was to facilitate an understanding of the hydraulic processes operating in the estuaries.

To achieve this aim a data collection program was established that involved monitoring various parameters in each estuary to characterise spatial and temporal variations. During the data collection period from 22 September to 28 November 2003 water levels were monitored at six sites within Merimbula Lake and five sites within Pambula Lake. No water level recorders were deployed in Back Lagoon because the entrance was closed. In addition, a short-term intensive data collection program was undertaken on 25 October 2003, during which tidal velocities were monitored at one site in Merimbula Lake and three sites in Pambula Lake over a spring, ebb-flood semi-diurnal tidal cycle.

The hydraulic characteristics of Merimbula and Pambula lakes are relatively simple, with the estuary exhibiting characteristics similar to a typical small lake system. Maximum ebb tidal flows were recorded approximately one to two hours after high tide, while maximum flood tidal flows were recorded approximately one to two hours before the next high tide. On both ebb and flood tides the minimum tidal flows (or slack water) were recorded from approximately one hour before, to one hour after, high and low water.

The tidal limit in Merimbula Creek occurs 450 m downstream from the bridge on the road from Merimbula to Tathra. The tidal limit in Boggy Creek occurs at a rise in the creek 60 m upstream from the Princes Highway bridge. The tidal limit in Bald Hills Creek occurs at the small rises in the creek 50 m downstream from the Princes Highway culverts. The tidal limit in the Pambula River occurs 100 m downstream from the Princes Highway. The tidal limit in the Yowaka River occurs at the bend in the river 250 m upstream from Pipeclay Creek.

Harmonic analysis of the long-term water level data was used to determine the difference between higher high water (spring solstices) and ISLW. This analysis showed that there was a gradual decrease in the tidal range along each estuary. In Merimbula Lake the range of 1.83 m recorded at the ocean gauge at Eden decreased to 1.52 m at Site 2 at Mitchies Beach, 1.39 m at Site 3 the permanent recorder at Merimbula Wharf, 1.31 m at Site 5 just upstream of the bridge, 0.42 m at Site 6, 0.78 m at Site 7 and 0.80 m at Site 8 the permanent recorder in the north-west corner of Merimbula Lake. In Pambula Lake the range of 1.83 m recorded at the ocean gauge at Eden decreased to 1.55 m at Site 9 at Pambula Lake entrance, 1.54 m at Site 12 the permanent recorder in the north-west corner of Pambula Lake, 0.68 m at Site 14 in the upper Pambula River and 1.04 m at Site 16 in the upper Yowaka River.

Tidal lags also varied along each estuary. At Site 2 in Merimbula Lake the mean phase lag was 21 minutes after the ocean tide, at Site 3 it was 42 minutes, at Site 5 it was 51 minutes, at Site 7 it was 156 minutes and at Site 8 it was 154 minutes. At Site 9 in Pambula Lake the mean phase lag was 3 minutes after the ocean tide and at Site 12 it was 79 minutes. A full summary of the times and levels of the tides recorded at each site on 25 October 2003 is shown in Tables B and C.

The maximum current velocity recorded at Site 4 in Merimbula Lake on the ebb tide was approximately 1.21 m/s and on the flood tide 1.24 m/s. The maximum current velocity recorded at Site 10 in Pambula River on the ebb tide was approximately 0.81 m/s and on the flood tide 0.91 m/s. Data from this exercise shows that throughout the estuaries there is typical vertical distribution of velocity. A full summary of the maximum velocities recorded at each site on 25 October 2003 is shown in Table E.

Spatial variations in water quality during the short-term intensive data collection program were investigated by undertaking water quality profiles at a total of twenty-nine selected sites in Merimbula Lake on 27 and 30 October 2003 and twelve selected sites in Pambula Lake on 27 and 28 October 2003, once at approximately high water and again at low water. Water quality profiles were also undertaken at a total of eight selected sites in Back Lagoon on 26 October 2003, although the lagoon was not open to the ocean.

From the data collected, which does not include information on nutrients or coliform levels, it can be concluded that on the day of the profiling the water quality in both Merimbula Lake and Pambula Lake was generally typical of an estuary influenced by tides and winds, with tidal forces having the greater impact. The measured parameters were all within the acceptable limits as recommended in the 1992 ANZECC water quality guidelines for fresh and marine waters.

The aim of this report is to describe the methodology adopted for each component of the data collection exercise and to present the results, the reduced data and relevant data from other sources. Other data collection exercises undertaken by MHL in Merimbula and Pambula lakes and Back Lagoon are listed in the references in Section 7.

Data Summary

From 22 September to 28 November 2003 a data collection exercise was undertaken in Merimbula Lake, Pambula Lake and Back Lagoon estuaries with the aim of providing baseline data and developing an understanding of the hydraulic processes operating in the three estuaries. The locations of all the data collection sites are shown in Figures 1.4, 1.5, 6.1 and 6.2. Water level data was available from four permanent sites, one at Eden, two in Merimbula Lake and one in Pambula Lake, and eight temporary sites that were deployed at other strategic sites within the study area, four in Merimbula Lake and four in Pambula Lake, for a period of approximately nine weeks. A summary of the available water level data is given in Table A.

Table A Summary of Available Water Level Data

Site No.	Site Name	Instrument	Period		Figure No.
			From	To	
0	Eden	EWS/Druck	Permanent water level site		A1
2	Merimbula Lake Mitchies Beach	Druck/RRDL3 03-76	1030 22/9/03	1515 28/11/03	A2
3	Merimbula Wharf	M2000	Permanent water level site		A3
5	Merimbula Lake Bridge	Druck/RRDL3 03-72	1115 22/9/03	1500 28/11/03	A4
6	Merimbula Lake South	Druck/RRDL3 03-77	0800 22/9/03	1415 28/11/03	A5
7	Merimbula Lake Centre	Druck/RRDL3 03-71	0900 22/9/03	1545 28/11/03	A6
8	Merimbula Lake North-West	M2000	Permanent water level site		A7
9	Pambula River Entrance	Druck/RRDL3 02-200	1430 22/9/03	1200 28/11/03	A8
11	Pambula Lake South-East	Druck/RRDL3 02-203	1500 22/9/03	1230 28/11/03	A9
12	Pambula Lake North-West	M2000	Permanent water level site		A10
14	Upper Pambula River	Druck/RRDL3 02-198	1715 22/9/03	1045 28/11/03	A11
16	Yowaka River	Druck/RRDL3 03-73	1630 22/9/03	1130 28/11/03	A12

A summary of the reduced water level data during the short-term intensive data collection program on 25 October 2003 is given in Tables B and C.

Table B Summary of Reduced Water Level Data - Merimbula Lake - 25 October 2003

Site Number	High Water		Low Water		Ebb Range (m)	High Water		Flood Range (m)
	Time (EST)	Level (m AHD)	Time (EST)	Level (m AHD)		Time (EST)	Level (m AHD)	
0	0730	0.55	1400	-0.83	1.38	1930	0.55	1.38
2	0745	0.48	1430	-0.64	1.12	2015	0.48	1.12
3	0815	0.47	1530	-0.52	0.99	2030	0.47	0.99
5	0830	0.39	1530	-0.52	0.91	2045	0.39	0.91
6	1030	0.34	1930	0.10	0.24	2230	0.34	0.24
7	0930	0.39	1730	-0.08	0.47	2145	0.37	0.45
8	0930	0.40	1738	-0.09	0.49	2145	0.38	0.47

Table C Summary of Reduced Water Level Data - Pambula Lake - 25 October 2003

Site Number	High Water		Low Water		Ebb Range (m)	High Water		Flood Range (m)
	Time (EST)	Level (m AHD)	Time (EST)	Level (m AHD)		Time (EST)	Level (m AHD)	
0	0730	0.55	1400	-0.83	1.38	1930	0.55	1.38
9	0800	0.50	1500	-0.56	1.06	2030	0.50	1.06
11	0845	0.54	~1545	<-0.40	>0.94	2100	0.54	>0.94
12	0900	0.54	1600	-0.52	1.06	2100	0.54	1.06
14	0915	0.56	1845	0.10	0.46	2115	0.57	0.47
16	0900	0.54	1800	-0.17	0.71	2100	0.53	0.70

Note: The sensor at Site 11 went dry at low water

A summary of the available current velocity and discharge data is presented in Table D.

Table D Summary of Available Velocity and Discharge Data

Site No.	Site Name	Instrument	Data Type	No. of Transects	25/10/2003	
					From	To
4	Merimbula Lake Bridge	ADCP	Profile	21	0830	2205
10	Pambula River Downstream	ADCP	Profile	30	0743	2116
13	Pambula River Upstream	ADCP	Profile	28	0812	2129
15	Yowaka River	ADCP	Profile	23	0819	2137

A summary of the velocity data and reduced discharge data for the intensive monitoring period on 25 October 2003 is given in Table E.

Table E Summary of Velocity and Discharge Data - 25 October 2003

Site No.	Maximum Velocity			Maximum Discharge			Tidal Prism	
	Ebb (m/s)	Flood (m/s)	Figure No.	Ebb (m^3/s)	Flood (m^3/s)	Figure No.	Ebb ($m^3 \times 10^6$)	Flood ($m^3 \times 10^6$)
4	1.21	1.24	C2	137	174	C1	2.31	2.05
10	0.81	0.91	C5	231	286	C4	3.19	3.75
13	0.21	0.25	C8	34	30	C7	0.34	0.34
15	0.16	0.21	C11	12	17	C10	0.15	0.15

Note: The maximum velocities are the highest velocities at peak discharge

Two sets of water quality profile data were collected with a Sea-Bird SBE 25-03 at a total of twenty-nine sites throughout Merimbula Lake on 27 and 30 October 2003, twelve sites throughout Pambula Lake on 27 and 28 October 2003 and eight sites throughout Back Lagoon on 26 October 2003. The following parameters were recorded: density, conductivity, temperature, salinity, dissolved oxygen, chlorophyll, photosynthetically activated radiation (PAR), turbidity and water level.

Instrument specifications, calibration and quality assurance procedures are on file at MHL. Water level data from Sites 0, 2, 3, 5, 6, 7, 8, 9, 11, 12, 14 and 16 are in Appendix A; ADCP transect filenames for Sites 4, 10, 13 and 15 are in Appendix B; discharge data from Sites 4, 10, 13 and 15 are in Appendix C; and water quality contour data from the high water and low water profiling are in Appendix D.

Table of Contents

List of Appendices

List of Tables - Text

List of Tables - Appendices

List of Figures - Text

List of Figures - Appendices

1. Site Details

The Merimbula Lake, Pambula Lake and Back Lagoon estuaries are located on the NSW south coast 360 km south of Sydney. The Merimbula Lake estuary has a catchment area of approximately 26 km^2 and a waterway area of 4.5 km^2. The lower catchment contains 3.3 km^2 of wetlands of which 0.38 km^2 are mangroves, 2.30 km^2 are seagrass and 0.63 km^2 are saltmarsh. The entrance is open and naturally trained along the northern side. Aerial photographs of the estuary taken on 22 April 2000 are shown in Figure 1.1. A detailed location map of the study area is shown in Figure 1.4. The Pambula Lake estuary has a catchment area of approximately 275 km^2 and a waterway area of 2.9 km^2. The lower catchment contains 1.5 km^2 of wetlands of which 0.45 km^2 are mangroves, 0.87 km^2 are seagrass and 0.19 km^2 are saltmarsh. The entrance is open and untrained. Aerial photographs of the estuary taken on 22 April 2000 are shown in Figure 1.2. A detailed location map of the study area is shown in Figure 1.5. The Back Lagoon estuary has a catchment area of approximately 23 km^2 and a waterway area of 0.8 km^2. The lower catchment contains 0.2 km^2 of wetlands of which 0.20 km^2 are seagrass and 0.02 km^2 are saltmarsh. The entrance is generally closed and untrained, although it is open in the aerial photographs of the estuary taken on 22 April 2000 that are shown in Figure 1.3. A detailed location map of the study area is shown in Figure 1.4.

As part of the DIPNR Estuary Management Program's work to provide an understanding of the hydraulic processes operating in these three estuaries, MHL undertook tidal flow, water level and water quality measurements in the area between 22 September and 28 November 2003. Descriptions of the data collection sites are listed in Table 1.1 and MGA coordinates of the sites are listed in Table 1.2.

Table 1.1 Description of Data Collection Sites

Site No.	Site Name	Site Description
0	Eden	Permanent ocean tide recorder at Eden
1	Meteorological Station	On edge of caravan park 430 m south-west from Short Point
2	Merimbula Lake Mitchies Beach	Temporary water level recorder 460 m upstream from entrance
3	Merimbula Wharf	Permanent water level recorder 145 m downstream from Highway bridge
4	Merimbula Lake Bridge	ADCP transect across Merimbula Lake 20 m upstream from Highway bridge
5	Merimbula Lake Bridge	Temporary water level recorder 160 m upstream from bridge near boat ramp
6	Merimbula Lake South-East	Temporary water level recorder in south-east corner of Merimbula Lake
7	Merimbula Lake Centre	Temporary water level recorder in centre of Merimbula Lake
8	Merimbula Lake North-West	Permanent water level recorder in north-west corner of Merimbula Lake
9	Pambula River Entrance	Temporary water level recorder 600 m upstream from entrance
10	Pambula River Downstream	ADCP transect across Pambula River 2.0 km upstream from entrance
11	Pambula Lake South-East	Temporary water level recorder in south-east corner of Pambula Lake
12	Pambula Lake North-West	Permanent water level recorder in north-west corner of Pambula Lake
13	Pambula River Upstream	ADCP transect across Pambula River 40 m upstream from Yowaka River
14	Upper Pambula River	Temporary water level recorder 2.0 km upstream from Yowaka River
15	Yowaka River	ADCP transect across Yowaka River 425 m upstream from Pambula River
16	Upper Yowaka River	Temporary water level recorder 1.0 km upstream from Princes Highway

Table 1.2 Location of Data Collection Sites

Site No.	Site Name	Site Location MGA 55	
		Easting	Northing
0	Eden	758429	5893182
1	Meteorological Station	761225	5913756
2	Merimbula Lake Mitchies Beach	760070	5912979
3	Merimbula Wharf	759300	5913041
4	Merimbula Lake Bridge	759205	5912912
5	Merimbula Lake Bridge	759269	5912751
6	Merimbula Lake South-East	757799	5910529
7	Merimbula Lake Centre	757545	5912703
8	Merimbula Lake North-West	756504	5913254
9	Pambula River Entrance	759180	5906805
10	Pambula River Downstream	758105	5906122
11	Pambula Lake South-East	758975	5903877
12	Pambula Lake North-West	756744	5905025
13	Pambula River Upstream	756603	5905873
14	Upper Pambula River	756034	5907367
15	Yowaka River	756241	5905617
16	Upper Yowaka River	755214	5904990

The coordinates given for Sites 4, 10, 13 and 15 are the approximate left bank starting point of the ADCP current metering lines

Water level data was available from four permanent sites; one at Eden (Site 0), two in Merimbula Lake (Sites 3 and 8) and one in Pambula Lake (Site 12). Eight temporary sites were established at other strategic locations within the estuary for a period of approximately nine weeks; four in Merimbula Lake (Sites 2, 5, 6 and 7) and four in Pambula Lake (Sites 9, 11, 14 and 16). Druck sensors with RRDL3 loggers were installed at all the temporary sites.

ADCP bottom-tracking profiling current meters were used to measure velocities at Sites 4, 10, 13 and 15 on 25 October 2003. A Sea-bird Seacat SBE25-03 water quality profiler was used to measure water quality profiles at a total of forty-nine selected locations throughout the three estuaries on 26, 27, 28 and 30 October 2003, as detailed in Section 6.

The cross-sections at Sites 4, 10, 13 and 15 were determined from the ADCP data on a transect close to high water, but bank slopes were not surveyed. The cross-sections are shown in Appendix C on both the current speed distribution stick plots and the contour plots.

Levelling was carried out by Mr C. Falzon from the Department of Commerce's Surveying and Spatial Information Services. Digital levelling using a Leica 2002 was used at all sites. Details of the benchmarks used are shown in Table 1.3.

Table 1.3 Details of Benchmarks Used

Site No.	Local Benchmark		Origin of Levels				Gauge Reference Mark	
	Description	RL (m AHD)	Description	RL (m AHD)	Accuracy	Source	Description	RL (m AHD)
2	Conc. nail placed in NW corner of conc. parking bay	1.480	PM 58818	1.588	V2	SCIMS	SM	2.354
5	(a) Conc. nail placed in timber beam of jetty. (b) Plug in kerb near EP	1.455 2.162	PM 28343 SSM 30613	1.396 2.149 2.154	V2	SCIMS Obs'd SCIMS	SM	2.053
6	GIP placed 2m off north side of track in council depot near tree line	0.710	SSM 23464	21.423	V2	SCIMS	SM	1.922
7	(a) SSM35320 (b) GI nail in post of timber walkway	0.755 (Obs'd) 0.870	SSM 1201	2.192	V1	SCIMS	SM	2.307
9	GI nail in base of sign post	1.219	PM 28418	3.176	V2	SCIMS	SM	1.783
11	GIP placed near old fence line	0.646	ML01	15.318	Photo Control	DIPNR	SM	2.718
14	GIP placed on bank	1.229	SSM 1206	26.420	V1	SCIMS	SM	2.818
16	GI nail placed in east edge of bitumen road	2.526	SSM 128489	13.679	Photo Control	DIPNR	SM	2.497

Note 1 SM for gauge reference mark description indicates the survey mark on the logger housing

Note 2 Due to gusting winds, water conditions and time constraints the observation distances at Site 7 were longer than normally accepted. Observations were taken to survey line, underside of cap and top of taper of the gauge housing

Note 3 Due to gusting winds, water conditions and time constraints observation distances at Site 8 where longer than normally accepted. Observations were taken to the board gauge

Note 4 Due to time constraints and gusting winds the local bench mark at Site 11 was levelled from ML01. Heights for ML01 and SSM 121450 were supplied by DIPNR from their GPS photo control survey

Note 5 Due to time constraints the local benchmark at Site 14 was only levelled one way

Looking south-west

Looking north-east

Looking east

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PHOTOGRAPHS OF MERIMBULA LAKE ESTUARY
22 APRIL 2000

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Figure 1.1

DRAWING 1290-1-01.CDR

Looking east

Looking south-east

Looking north-west

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PHOTOGRAPHS OF PAMBULA LAKE ESTUARY

22 APRIL 2000

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Figure 1.2

DRAWING 1290-1-02.CDR

Looking south-west

Looking south-east

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PHOTOGRAPHS OF BACK LAGOON ESTUARY
22 APRIL 2000

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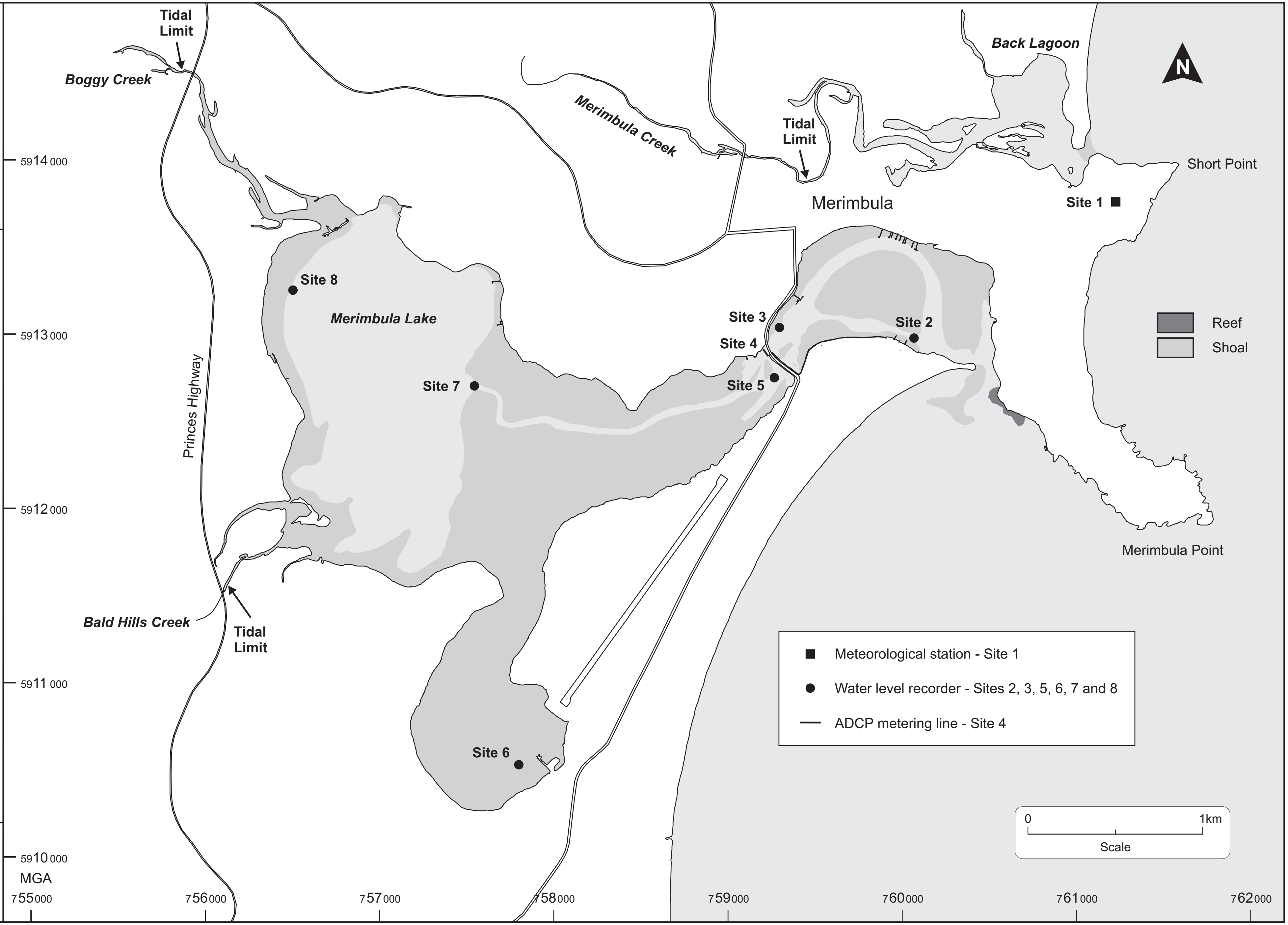
Figure 1.3

DRAWING 1290-1-03.CDR



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DETAILED LOCATION MAP
MERIMBULA LAKE STUDY AREA

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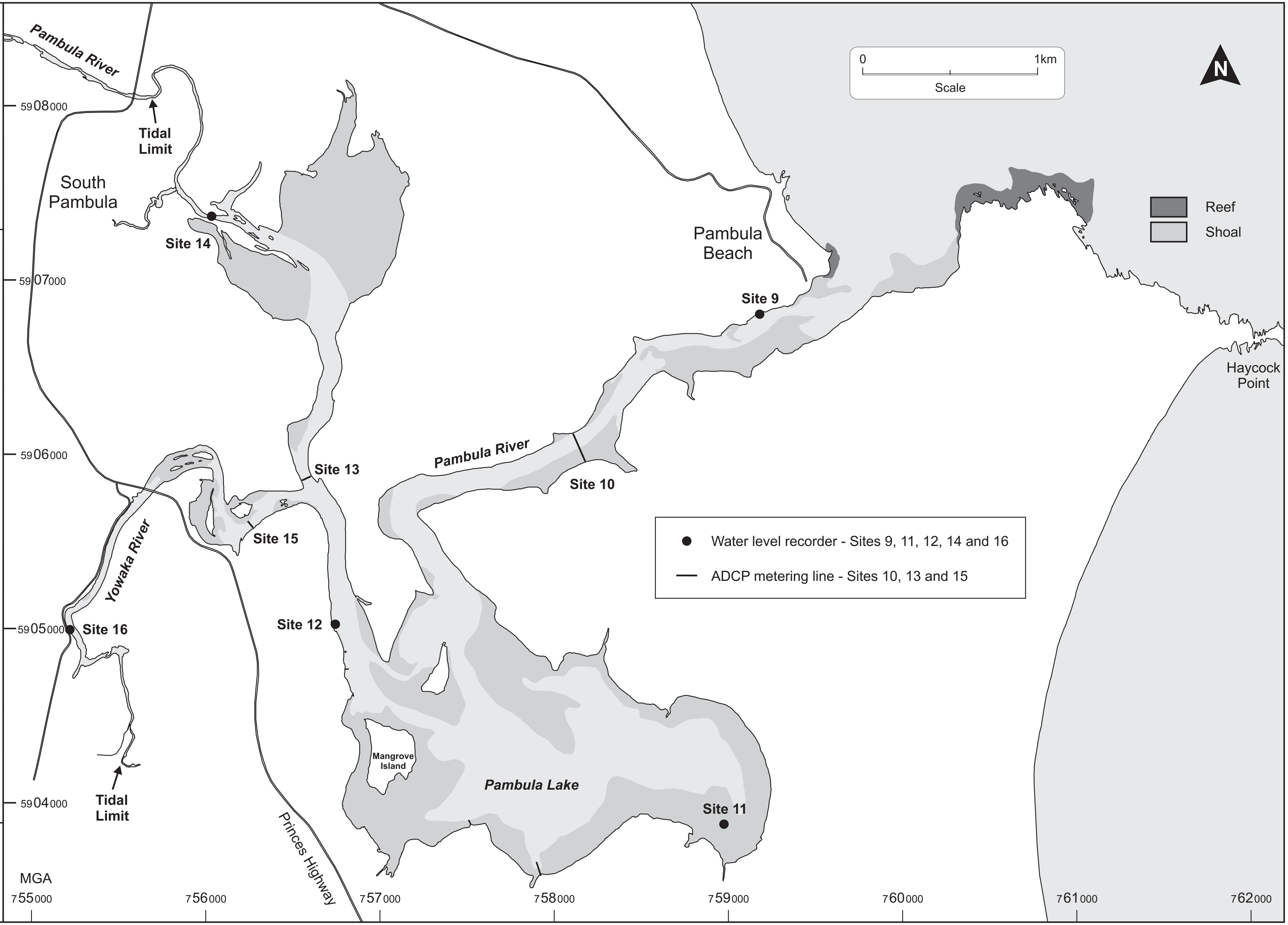
Figure 1.4

DRAWING 1290-1-04.CDR



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DETAILED LOCATION MAP
PAMBULA LAKE STUDY AREA

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Figure 1.5
DRAWING 1290-1-05.CDR

2. Weather and Freshwater Flow

2.1 Weather

To ensure that relevant meteorological data would be available from a location close to the study area, a temporary meteorological station was established at Site 1 on the edge of the caravan park near Short Point (see Figure 1.4). This station consisted of an RM Young wind monitor model 05103 (measuring wind speed and direction every 2 seconds and recording 15-minute averages), a Kipp and Zonen pyranometer CM6B (measuring solar irradiance), a Vaisala HMP 35A humidity and temperature probe and a Vaisala analog barometer PTB100A (all recording instantaneous readings every 15 minutes). Details of the specifications and calibration procedures for these instruments are on file at MHL. The data recorded is shown in Figure 2.1. Daily rainfall data recorded at Merimbula Airport by the Bureau of Meteorology from September to November 2003 is shown in Table 2.1.

Table 2.1 Daily Rainfall at Merimbula Airport - September to November 2003 (from Bureau of Meteorology - rainfall to 0900 hours)

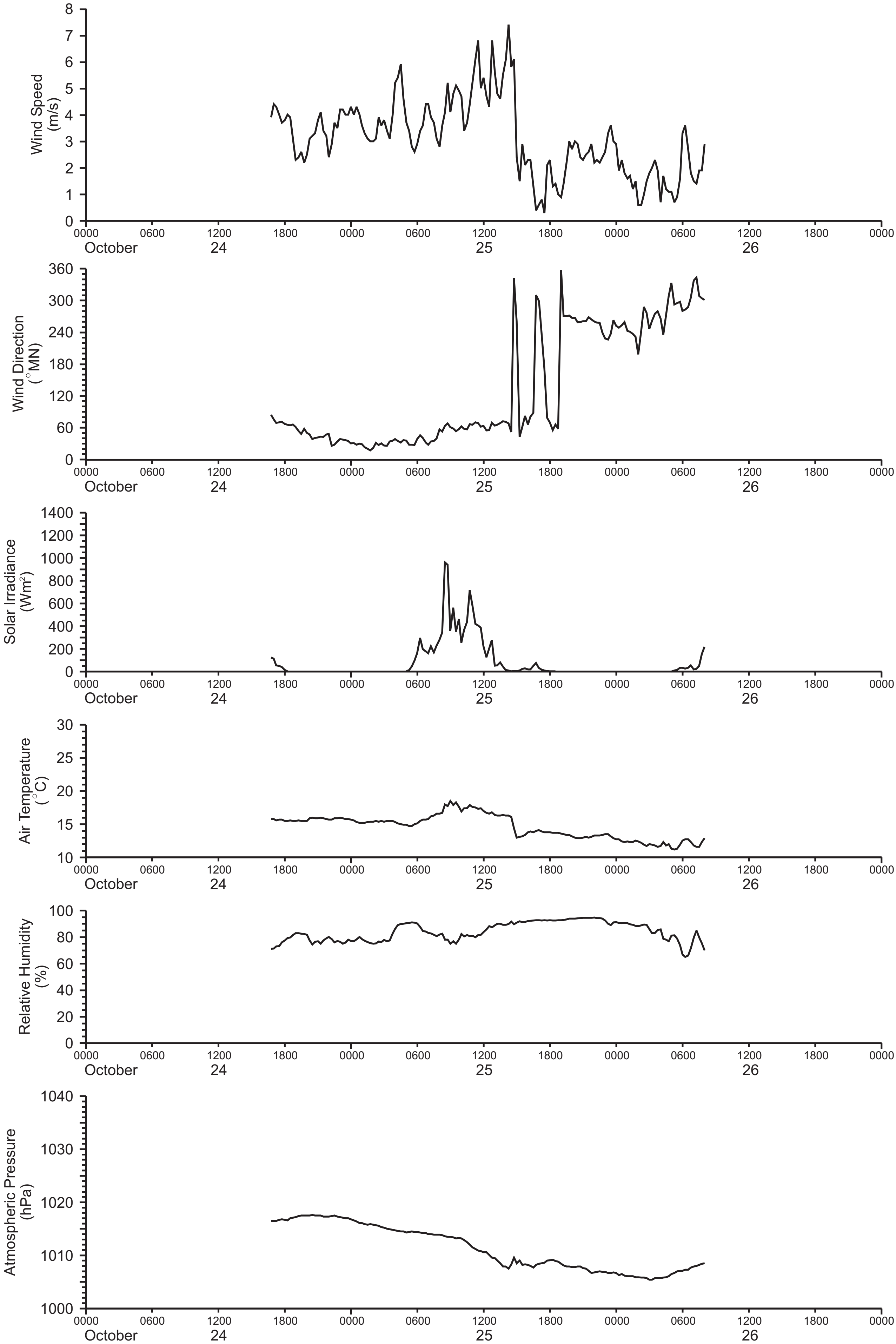
September	(mm)	October	(mm)	November	(mm)
1	0.2	1	0.0	1	0.0
2	0.0	2	6.0	2	1.0
3	0.0	3	3.0	3	0.2
4	0.0	4	0.2	4	0.0
5	0.0	5	0.0	5	0.0
6	0.0	6	17.0	6	0.0
7	0.0	7	0.2	7	-
8	0.2	8	0.0	8	0.0
9	0.0	9	0.0	9	0.2
10	0.0	10	0.0	10	0.0
11	2.0	11	3.0	11	0.0
12	0.0	12	2.0	12	0.0
13	0.2	13	0.2	13	0.0
14	0.0	14	0.0	14	0.0
15	1.0	15	0.0	15	-
16	0.0	16	1.0	16	0.0
17	0.0	17	0.0	17	23.0
18	0.0	18	0.0	18	1.0
19	0.0	19	0.0	19	0.0
20	0.4	20	-	20	0.2
21	0.6	21	0.0	21	3.0
22	0.2	22	1.0	22	25.0
23	0.0	23	0.0	23	27.0
24	0.8	24	3.0	24	2.0
25	0.0	25	0.0	25	0.0
26	0.0	26	24.0	26	0.4
27	2.0	27	0.2	27	0.0
28	0.0	28	0.0	28	0.0
29	0.0	29	5.0	29	0.0
30	0.0	30	0.0	30	0.0

2.2 Southern Oscillation Index

The Southern Oscillation Index (SOI) gives a simple measure of the status of the Walker Circulation - a major wind pattern of the Asia/Pacific region whose variability has a marked effect on weather conditions in the Southern Hemisphere. The SOI is calculated from the monthly or seasonal fluctuations in the air pressure difference between Tahiti and Darwin. The SOI is the standardised anomaly of the mean sea level pressure difference between Tahiti and Darwin. El Nino is the name given to episodes of the weather circulation where the Pacific trade winds weaken. In Australia this leads to a reduction of the ocean temperatures on the east coast and sometimes drought. La Nina is the name given to the alternate phase of the weather circulation to El Nino. During La Nina episodes the Pacific trade winds are re-established and in Australia, ocean temperatures increase on the east coast. During the La Nina phase higher than average rainfall is experienced in eastern and northern Australia. On the western coast of the Americas the wet/dry climatic effects of the La Nina and El Nino phases are the opposite to those experienced on the east coast of Australia. Positive values of the SOI indicate La Nina events whilst negative values indicate El Nino events. The higher the absolute value of the SOI, the larger the strength of the La Nina/El Nino influence. As shown in Figure 2.2, in all but one of the twelve months preceding this data collection the SOI values were negative, indicating a dry El Nino phase. The data plotted in Figure 2.2 was obtained from the Bureau of Meteorology's web site (BoM 2003).

2.3 Freshwater Flow

The three estuaries are so small that there are no stream gauging stations located in any of the catchments. Therefore, there are no records of freshwater flow.



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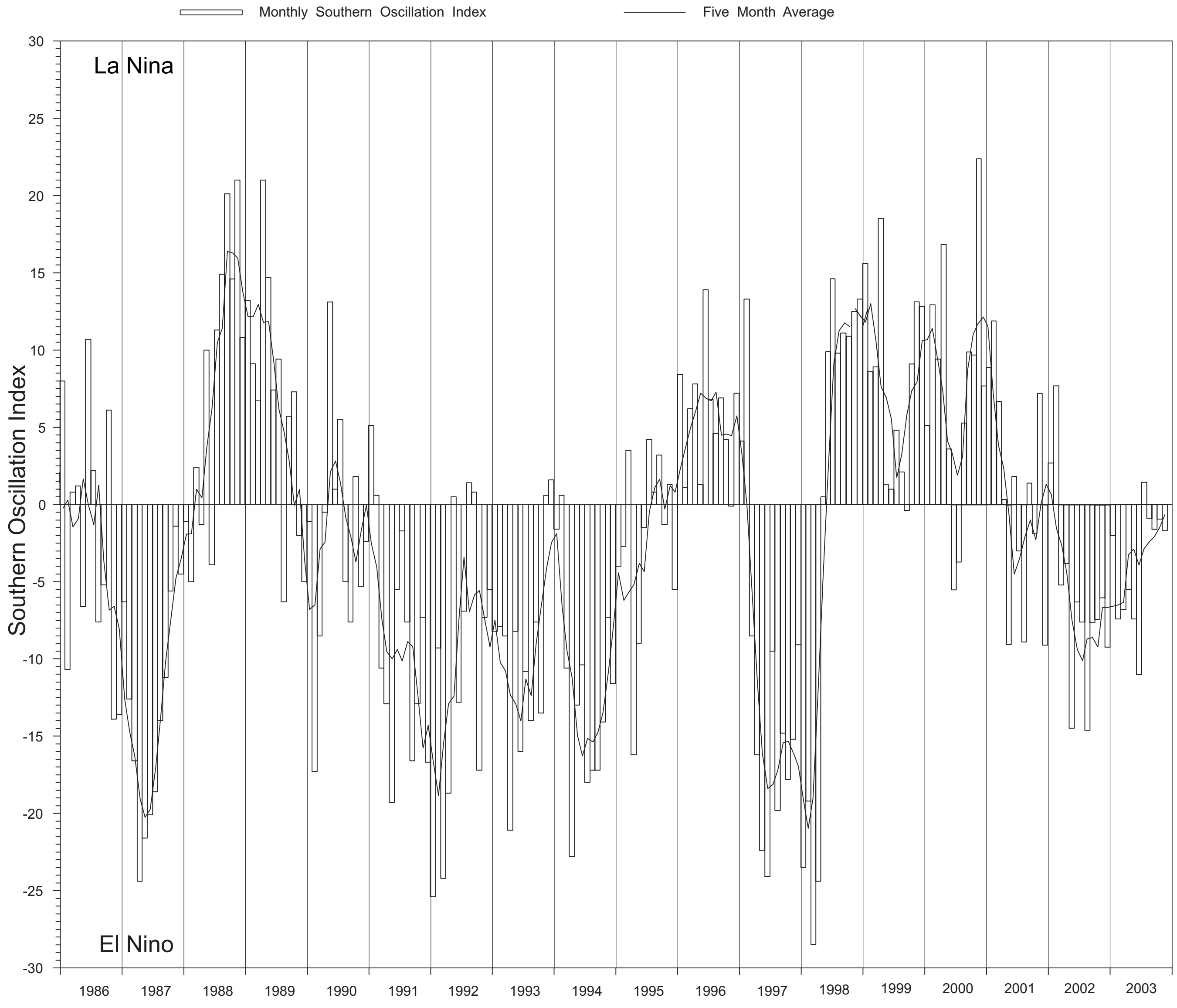
SITE 1 - METEOROLOGICAL DATA
24 TO 26 OCTOBER 2003

MHL Report 1290

Figure 2.1

DRAWING 1290-2-01.CDR



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SOUTHERN OSCILLATION INDEX

1986 - 2003

MHL Report 1290

Figure 2.2

DRAWING 1290-2-02.CDR

3. Water Level Data

The aim of this component of the data collection exercise was to provide a comprehensive data set defining tidal variations in water level throughout the study areas during the monitoring period, from 22 September to 28 November 2003. Water levels were monitored by permanent automatic water level recorders (AWLR) deployed at Sites 0, 3, 8 and 12; and by temporary AWLRs deployed at Sites 2, 5, 6, 7, 9, 11, 14 and 16. The locations of all water level sites are shown in Figures 1.4 and 1.5 and photographs of the sites are shown in Figures 3.1 and 3.2. Details of the instrumentation deployed are presented in Table 3.1.

Table 3.1 Details of Automatic Water Level Recorders Deployed

Site No.	Type of Instrument	Recording Rate (minutes)	Type of Deployment	Accuracy (cm)	Resolution (cm)
0	EWS/Druck	15	Permanent	± 1.0	1.0
3, 8 and 12	M2000	15	Permanent	± 0.5	0.10
2, 5, 6, 7, 9, 11, 14 and 16	HS RDL3-AN	15	Temporary	± 1.0	0.10

Note 1 The accuracy and resolution stated are the manufacturer's specification. This accuracy may vary according to field conditions and this resolution may not be plotted if it does not represent the appropriate accuracy

Note 2 Monitoring at all sites was in accordance with MHL's Quality Assurance work instructions

Both the Greenspan and Druck pressure sensors are vented to the atmosphere and so the data is automatically corrected for the effects of barometric pressure. Therefore, the measured data represent the pressures exerted by the column of water above the sensor. Before being stored in memory, these pressures are converted to water depths according to the following equation (AS 1376):

$$\mathbf{d = p \times (1 \div \rho) \times (1 \div g)}$$

where **d** is the water depth in millimetres, **p** is the pressure in Pascals, ρ is the water density in kg/m^3 and **g** is the acceleration due to gravity, which is assumed to be constant at 9.80665 m/s^2. The internal processing parameters in the instruments assume a density of fresh water (998.2042 kg/m^3) for calibration purposes and therefore, during the data reduction process the recorded data were corrected for the variation in water density at the site of deployment. A mean value for water density was determined for each site from the temperature and salinity data recorded in the Sea-Bird profiles. These raw water level data were then reduced to AHD and quality controlled by verification with manual observations according to MHL's quality assurance procedures. The full data set for each site is presented graphically in Appendix A.

The data from all sites was analysed to determine the tidal planes and tidal ranges along the estuary using the Foreman method of tidal height analysis (Foreman 1977). With this procedure a maximum of 69 harmonic tidal constituents can be generated from a 366-day period of continuously recorded data. The major tidal constituents determined from this analysis are the semi-diurnal constituents M_2 and S_2, and the diurnal constituents K_1 and O_1.

Periods of data shorter than 366 days can be used to generate these four major constituents, but 29 days (one complete lunar cycle) is considered to be the minimum. Data for the fifty-five day period from 22 September to 17 November 2003 was used to calculate the tidal planes presented in Tables 3.2 and 3.3 and Figures 3.3 and 3.4. The tidal ranges are shown in Tables 3.4 and 3.5.

Unfortunately the instrument at Site 11 was not deployed correctly and the sensor went dry when the water level dropped below approximately -0.40 m AHD. Therefore, reliable tidal planes and ranges could not be determined for this site.

It should be noted that when the Foreman method of analysis is used to calculate tidal planes at estuarine rather than ocean tide sites the accuracy and relevance of the analysis is influenced by shallow water effects. Therefore, the results obtained using this method to analyse the data from Merimbula Lake and Pambula Lake should be interpreted accordingly. The water levels in the estuary are influenced by the ocean semi-diurnal tidal cycle but in some locations these effects are superimposed over a fortnightly cycle related to the ocean spring and neap tides. Water levels may be 'pumped up' during spring tides and then 'drain' during neap tides (NSW Government 1992).

Table 3.2 Comparison of Tidal Planes - Merimbula Lake

Tidal Planes	Ocean	Merimbula Lake					
	Site 0 (m AHD)	Site 2 (m AHD)	Site 3 (m AHD)	Site 5 (m AHD)	Site 6 (m AHD)	Site 7 (m AHD)	Site 8 (m AHD)
HHW(SS)	0.831	0.723	0.708	0.642	0.363	0.474	0.487
MHWS	0.434	0.410	0.412	0.360	0.227	0.255	0.262
MHW	0.323	0.304	0.318	0.273	0.203	0.213	0.218
MHWN	0.212	0.198	0.224	0.187	0.179	0.170	0.175
MTL	-0.139	-0.079	-0.031	-0.055	0.132	0.055	0.056
MLWN	-0.491	-0.356	-0.286	-0.297	0.085	-0.060	-0.062
MLW	-0.602	-0.462	-0.380	-0.383	0.061	-0.103	-0.106
MLWS	-0.713	-0.568	-0.474	-0.469	0.037	-0.145	-0.149
ISLW	-0.997	-0.792	-0.685	-0.671	-0.060	-0.302	-0.310

Table 3.3 Comparison of Tidal Planes - Pambula Lake

Tidal Planes	Ocean	Pambula River/Lake			Yowaka
	Site 0 (m AHD)	Site 9 (m AHD)	Site 12 (m AHD)	Site 14 (m AHD)	Site 16 (m AHD)
HHW(SS)	0.831	0.721	0.754	0.535	0.567
MHWS	0.434	0.392	0.417	0.348	0.309
MHW	0.323	0.283	0.316	0.307	0.245
MHWN	0.212	0.173	0.216	0.267	0.180
MTL	-0.139	-0.101	-0.063	0.168	0.010
MLWN	-0.491	-0.376	-0.342	0.070	-0.160
MLW	-0.602	-0.485	-0.442	0.030	-0.225
MLWS	-0.713	-0.595	-0.543	-0.011	-0.289
ISLW	-0.997	-0.830	-0.784	-0.145	-0.473

HHW(SS) - Higher High Water (Spring Solstices)
MHWS - Mean High Water Springs
MHW - Mean High Water
MHWN - Mean High Water Neaps
MTL - Mean Tide Level
MLWN - Mean Low Water Neaps
MLW - Mean Low Water
MLWS - Mean Low Water Springs
ISLW - Indian Spring Low Water

Table 3.4 Comparison of Tidal Ranges - Merimbula Lake

Tidal Range	Ocean Site 0 (m AHD)	Merimbula Lake					
		Site 2 (m AHD)	Site 3 (m AHD)	Site 5 (m AHD)	Site 6 (m AHD)	Site 7 (m AHD)	Site 8 (m AHD)
HHW(SS) to ISLW	1.828	1.515	1.393	1.313	0.423	0.777	0.796
Mean Spring	1.147	0.978	0.886	0.829	0.190	0.401	0.411
Mean	0.926	0.766	0.698	0.656	0.142	0.315	0.324
Mean Neap	0.704	0.554	0.510	0.484	0.094	0.230	0.237

Table 3.5 Comparison of Tidal Ranges - Pambula Lake

Tidal Range	Ocean Site 0 (m AHD)	Pambula River/Lake			
		Site 9 (m AHD)	Site 12 (m AHD)	Site 14 (m AHD)	Site 16 (m AHD)
HHW(SS) to ISLW	1.828	1.551	1.538	0.680	1.041
Mean Spring	1.147	0.986	0.959	0.358	0.599
Mean	0.926	0.768	0.759	0.278	0.469
Mean Neap	0.704	0.550	0.558	0.197	0.340

A comparison of the four major harmonic constituents (none inferred) derived from the tidal analysis of the data from each site in Merimbula Lake, as well as the residual error from each analysis, is shown in Table 3.6. The constituents for Pambula Lake are shown in Table 3.7.

Table 3.6 Tidal Constituents (None Inferred) and Residual Errors - Merimbula Lake

Site	Constituent	Frequency (cycles/hour)	Period (hours)	Mean Amplitude (m)	G-Phase (degrees)	Theoretical Residual Error
0	O_1	0.0387307	25.82	0.1112990	67.74	0.09349
	K_1	0.0417807	23.93	0.1474259	101.79	
	M_2	0.0805114	12.42	0.4628139	239.56	
	S_2	0.0833333	12.00	0.1317463	246.12	
2	O_1	0.0387307	25.82	0.0978496	84.46	0.09192
	K_1	0.0417807	23.93	0.1261155	117.22	
	M_2	0.0805114	12.42	0.3830523	249.50	
	S_2	0.0833333	12.00	0.1058421	257.25	
3	O_1	0.0387307	25.82	0.0927846	94.53	0.08961
	K_1	0.0417807	23.93	0.1185754	125.73	
	M_2	0.0805114	12.42	0.3488717	258.76	
	S_2	0.0833333	12.00	0.0940738	267.30	
5	O_1	0.0387307	25.82	0.0887976	99.50	0.09051
	K_1	0.0417807	23.93	0.1129488	129.96	
	M_2	0.0805114	12.42	0.3281267	262.95	
	S_2	0.0833333	12.00	0.0862470	272.38	
6	O_1	0.0387307	25.82	0.0469057	167.54	0.05835
	K_1	0.0417807	23.93	0.0498239	201.70	
	M_2	0.0805114	12.42	0.0710279	340.29	
	S_2	0.0833333	12.00	0.0241745	358.16	
7	O_1	0.0387307	25.82	0.0741680	140.50	0.06246
	K_1	0.0417807	23.93	0.0824097	170.82	
	M_2	0.0805114	12.42	0.1576326	306.43	
	S_2	0.0833333	12.00	0.0427499	320.49	
8	O_1	0.0387307	25.82	0.0763032	140.54	0.06353
	K_1	0.0417807	23.93	0.0843021	172.08	
	M_2	0.0805114	12.42	0.1619458	307.91	
	S_2	0.0833333	12.00	0.0435678	321.93	

Table 3.7 Tidal Constituents (None Inferred) and Residual Errors - Pambula Lake

Site	Constituent	Frequency (cycles/hour)	Period (hours)	Mean Amplitude (m)	G-Phase (degrees)	Theoretical Residual Error
0	O_1	0.0387307	25.82	0.1112990	67.74	0.09349
	K_1	0.0417807	23.93	0.1474259	101.79	
	M_2	0.0805114	12.42	0.4628139	239.56	
	S_2	0.0833333	12.00	0.1317463	246.12	
9	O_1	0.0387307	25.82	0.1058233	74.70	0.10891
	K_1	0.0417807	23.93	0.1295049	107.01	
	M_2	0.0805114	12.42	0.3839989	238.71	
	S_2	0.0833333	12.00	0.1091442	247.55	
12	O_1	0.0387307	25.82	0.1066864	97.77	0.08358
	K_1	0.0417807	23.93	0.1346629	132.31	
	M_2	0.0805114	12.42	0.3793390	277.61	
	S_2	0.0833333	12.00	0.1002262	293.03	
14	O_1	0.0387307	25.82	0.0656694	125.11	0.05811
	K_1	0.0417807	23.93	0.0684076	155.46	
	M_2	0.0805114	12.42	0.1387993	278.88	
	S_2	0.0833333	12.00	0.0403276	305.89	
16	O_1	0.0387307	25.82	0.0880401	116.06	0.07084
	K_1	0.0417807	23.93	0.0961357	146.65	
	M_2	0.0805114	12.42	0.2346004	281.46	
	S_2	0.0833333	12.00	0.0646567	300.83	

Comparisons of tidal phase differences in minutes between each site and the ocean tide at Eden were also calculated based on only the spring and neap tides for the same period as the tidal analysis (22 September to 17 November 2003). The results for Merimbula Lake and Pambula Lake are shown in Tables 3.8 and 3.9 respectively. Due to the atypical tidal data at Sites 6, 14 and 16 and no low water data at Site 11, tidal phase differences could not be calculated for these sites.

Table 3.8 Tide Phase Differences for Springs and Neaps - Merimbula Lake

Site	Spring/Neap	Mean (minutes)	SD (minutes)	Minimum (minutes)	Maximum (minutes)
2	MHWS	13	5.0	4	20
	MLWS	39	8.0	28	49
	Mean Springs	26	14.6	4	49
	MHWN	4	5.7	-5	11
	MLWN	26	12.1	2	37
	Mean Neaps	15	14.6	-5	37
	Mean of All	21	15.7	-5	49
3	MHWS	29	7.8	17	38
	MLWS	67	9.7	54	80
	Mean Springs	48	20.9	17	80
	MHWN	18	8.6	0	26
	MLWN	50	13.4	24	62
	Mean Neaps	34	19.6	0	62
	Mean of All	42	21.6	0	80
5	MHWS	46	13.7	21	61
	MLWS	74	10.2	60	87
	Mean Springs	60	18.3	21	87
	MHWN	26	14.4	-1	45
	MLWN	53	15.3	24	68
	Mean Neaps	39	20.0	-1	68
	Mean of All	51	21.6	-1	87
7	MHWS	105	4.4	100	113
	MLWS	211	13.8	193	234
	Mean Springs	158	53.7	100	234
	MHWN	104	12.3	90	126
	MLWN	201	67.2	109	298
	Mean Neaps	152	68.5	90	298
	Mean of All	156	60.5	90	298
8	MHWS	106	5.1	100	115
	MLWS	213	14.3	193	237
	Mean Springs	159	54.5	100	237
	MHWN	103	24.1	51	126
	MLWN	193	56.8	107	256
	Mean Neaps	148	62.7	51	256
	Mean of All	154	58.4	51	256

Note Tidal phase differences could not be calculated for Site 6 due to atypical tidal data

Table 3.9 Tide Phase Differences for Springs and Neaps - Pambula Lake

Site	Spring/Neap	Mean (minutes)	SD (minutes)	Minimum (minutes)	Maximum (minutes)
9	MHWS	1	8.6	-14	14
	MLWS	21	8.8	8	34
	Mean Springs	11	13.4	-14	34
	MHWN	-12	7.6	-27	-6
	MLWN	-3	12.4	-23	13
	Mean Neaps	-7	11.3	-27	13
	Mean of All	3	15.5	-27	34
12	MHWS	66	4.9	57	73
	MLWS	109	5.7	100	118
	Mean Springs	88	22.3	57	118
	MHWN	50	3.7	42	53
	MLWN	83	16.5	62	101
	Mean Neaps	66	20.6	42	101
	Mean of All	79	24.0	42	118

Note Tidal phase differences could not be calculated for Sites 14 and 16 due to atypical tidal data

The data from the permanent ocean tide gauge at Eden was used so that the water level data collected in Merimbula and Pambula lakes could be related to ocean water levels. The predicted tides at Site 0 - Eden for the day of the intensive monitoring period on 25 October 2003 are presented in Table 3.10. The actual recorded tides are also presented for the purposes of comparison to show any barometric influence on the actual water levels.

Table 3.10 Predicted and Actual Tide Levels - 25 October 2003
Site 0 (Eden), Site 3 (Merimbula Wharf) and Site 12 (Pambula Lake North-West)

Site	Tide Level	Predicted			Actual		
		Time (EST)	Height (m AHD)	Range (m)	Time (EST)	Height (m AHD)	Range (m)
0	High	0745	0.69	-	0730	0.55	-
	Low	1353	-0.67	1.36	1400	-0.83	1.38
	High	2008	0.65	1.32	1930	0.55	1.38
3	High	0815	0.60	-	0815	0.47	-
	Low	1508	-0.34	0.94	1530	-0.52	0.99
	High	2030	0.60	0.94	2030	0.47	0.99
12	High	0853	0.67	-	0900	0.54	-
	Low	1553	-0.42	1.09	1600	-0.52	1.06
	High	2115	0.65	1.07	2100	0.54	1.06

Comparisons of the water level in the ocean and water levels throughout Merimbula Lake on 25 October 2003 are presented in Figure 3.5. Comparisons of the water level in the ocean and water levels throughout Pambula Lake on 25 October 2003 are presented in Figure 3.6.

Site 2 - Looking south

Site 3 - Looking upstream

Site 5 - Looking downstream

Site 6 - Looking west

Site 7 - Looking west

Site 8 - Looking west

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PHOTOGRAPHS OF THE WATER LEVEL RECORDERS
MERIMBULA LAKE - 22 SEPTEMBER 2003

MHL Report 1290

Figure 3.1

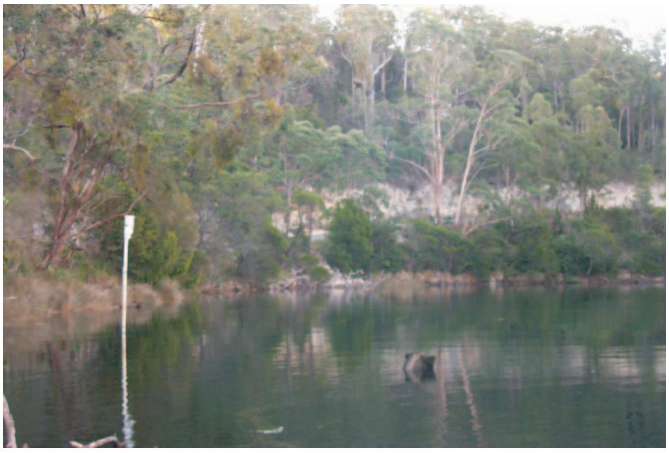
DRAWING 1290-3-01.CDR

Site 9 - Looking downstream

Site 11 - Looking north

Site 12 - Looking downstream

Site 14 - Looking downstream



Site 16 - Looking downstream

NSW Department of Commerce MANLY HYDRAULICS LABORATORY	PHOTOGRAPHS OF THE WATER LEVEL RECORDERS PAMBULA LAKE - 22 SEPTEMBER 2003	MHL Report 1290 Figure 3.2 DRAWING 1290-3-02.CDR

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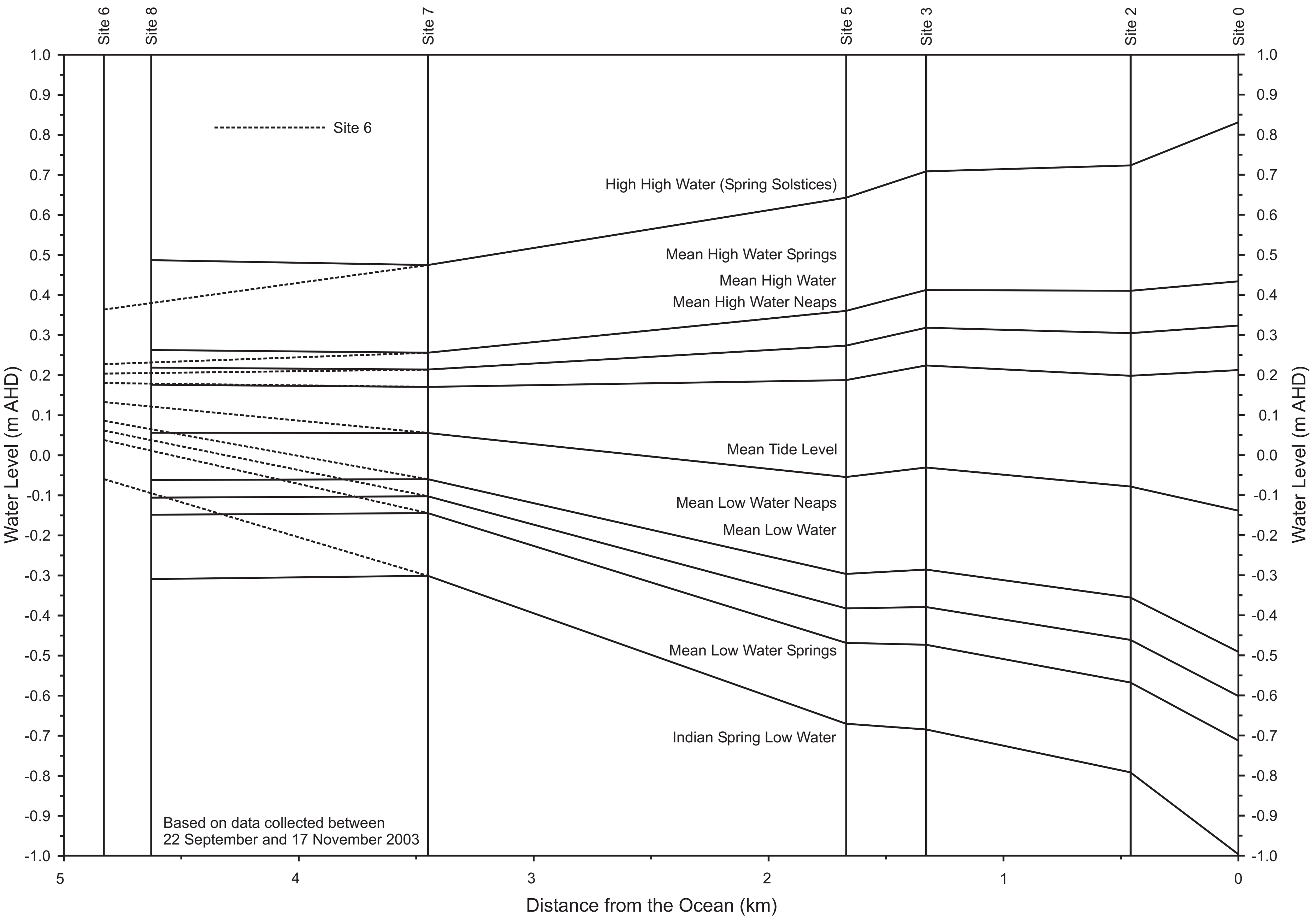
TIDAL PLANES - MERIMBULA LAKE
SITES 0, 2, 3, 5, 6, 7 AND 8



MHL Report 1290

Figure 3.3

DRAWING 1250-3-03.CDR

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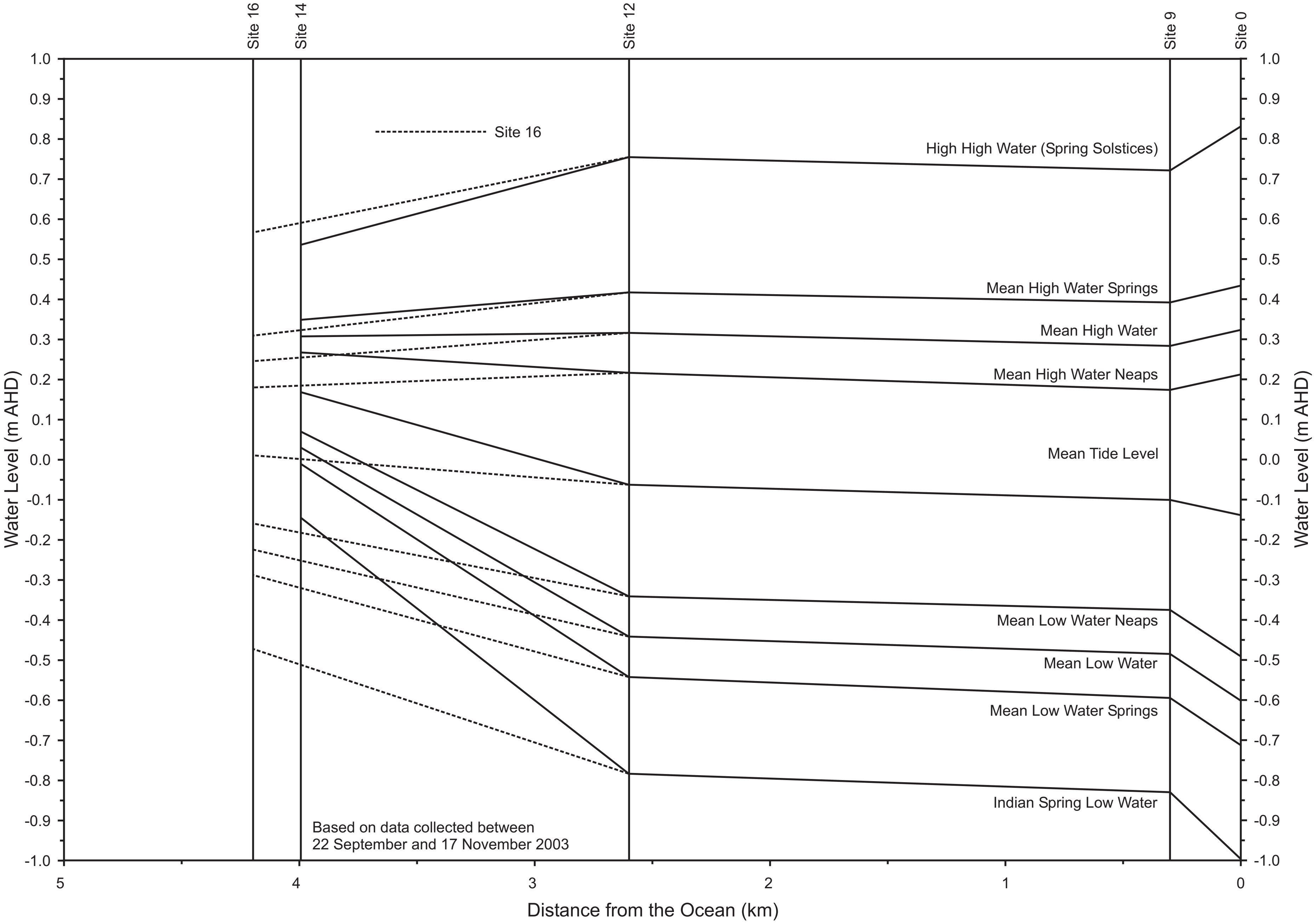
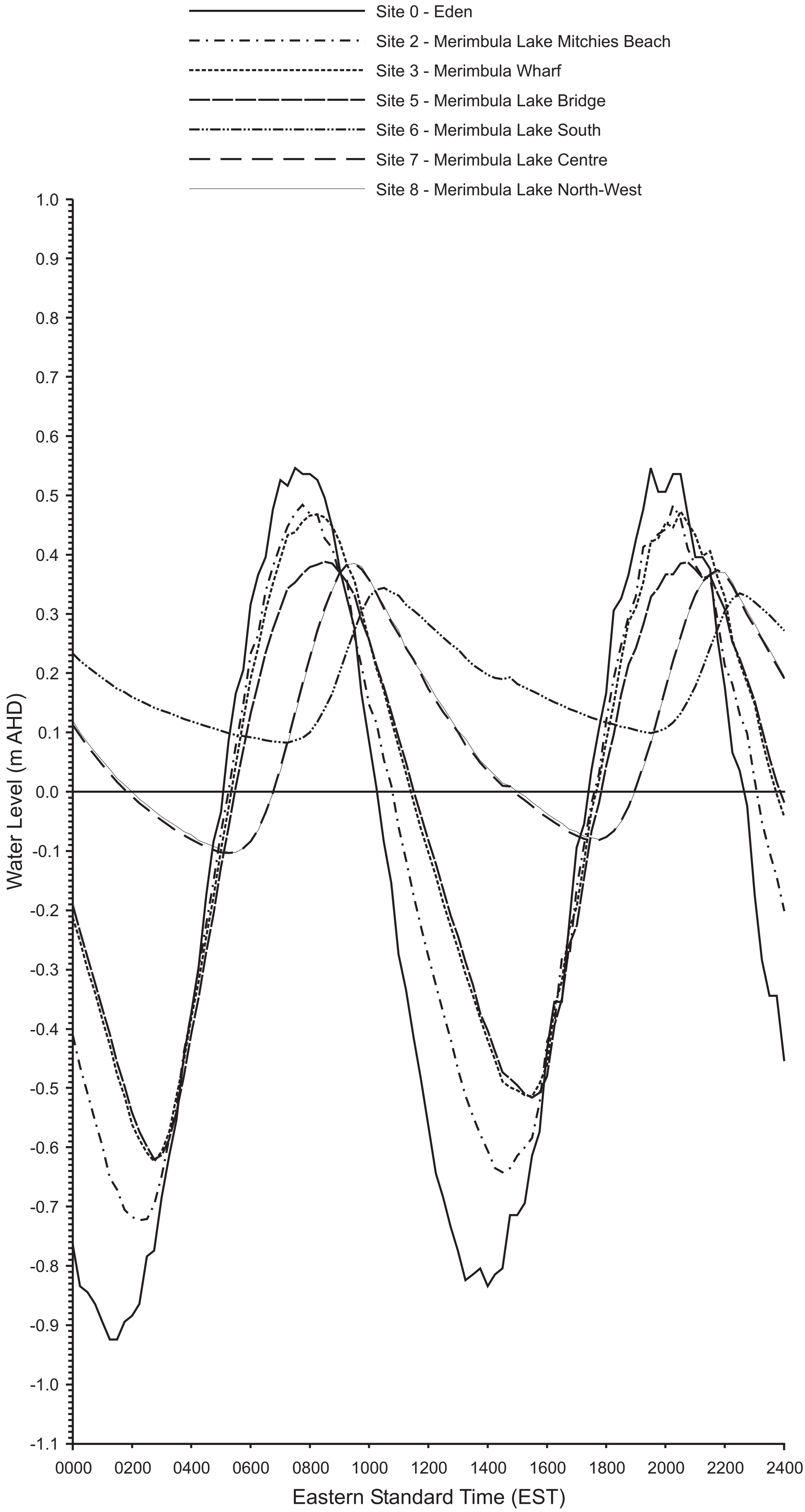
TIDAL PLANES - PAMBULA LAKE
SITES 0, 9, 12, 14 AND 16



MHL Report 1290
Figure 3.4

DRAWING 1250-3-04.CDR



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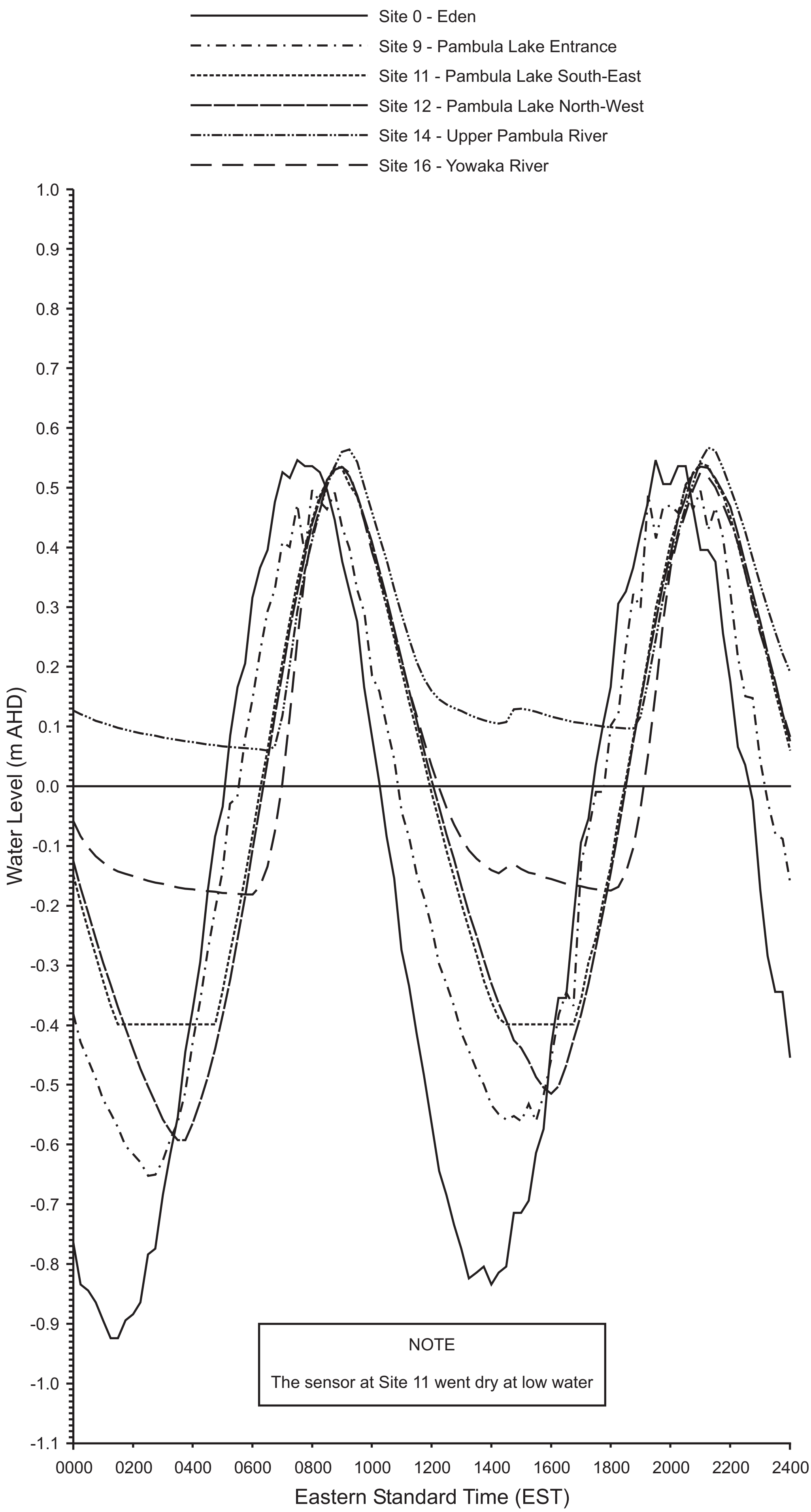
COMPARISON OF WATER LEVELS - MERIMBULA LAKE
SITES 0, 2, 3, 5, 6, 7 AND 8 - 25 OCTOBER 2003

MHL Report 1290

Figure 3.5

DRAWING 1290-3-05.CDR



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COMPARISON OF WATER LEVELS - PAMBULA LAKE
SITES 0, 2, 3, 5, 6, 7 AND 8 - 25 OCTOBER 2003

MHL Report 1290

Figure 3.6

DRAWING 1290-3-06.CDR

4. Velocity Data

Tidal velocity readings at the metering sites began before high water slack at 0743 hours (EST) on 25 October 2003 and continued until reversal of flow following the next high water at 2207 hours (EST). This was done so that velocity measurements were taken over a complete ebb and flood cycle, enabling the total ebb and flood volumes to be calculated (see Section 5). The typical maximum velocities at peak discharge on the ebb and flood tide are shown in Table 4.1. These are representative velocities, and actual velocities recorded at one particular point may have been slightly higher.

Table 4.1 Typical Maximum Velocities at Peak Discharge

Site No.	Ebb				Flood			
	Velocity (m/s)	**Distance from Left Bank (m)**	**Depth (m)**	**Time (EST)**	**Velocity (m/s)**	**Distance from Left Bank (m)**	**Depth (m)**	**Time (EST)**
4	1.21	34	3.61	1217	1.24	37	2.11	2035
10	0.81	42	1.14	1036	0.91	97	1.15	1824
13	0.21	51	1.24	1005	0.25	51	2.74	1959
15	0.16	28	1.74	1210	0.21	23	1.24	1936

Note 1 These velocities are taken directly from the peak discharge stick plots shown in Appendix C
Note 2 The ADCP readings do not include the surface shadow zone where actual velocities may be higher

Due to a rocky shoal between Sites 13 and 15 there was a three-hour period when low water level prevented access to Site 15.

4.1 Acoustic Doppler Current Profiling

RD Instruments Workhorse acoustic doppler current profilers (ADCP), which have bottom tracking capability, were used to measure tidal velocities at Sites 4, 10, 13 and 15. The technique involving the vessel-mounted ADCP facilitates direct, real-time measurement of discharge in the time taken for the vessel to traverse the section, with little or no previous site survey. The method is described in detail in Gordon (1989) and Simpson and Oltman (1990). A brief description of the principles of operation of the ADCP and its use in discharge measurement is given below.

The technique of acoustic doppler profiling is now commonly used in the study of three-dimensional flow structures. The ADCP transmits bursts of sound at a known frequency into the water column. The sound is scattered by plankton-sized particles (reflectors) carried by the water currents and some is received back by the ADCP which listens for echoes. As echoes are received from deeper in the water column the ADCP assigns different water depths (depth cells) to corresponding parts of the echo record. This enables the ADCP to define vertical profiles. The motion of the reflectors relative to the ADCP causes the echo to change frequency by an amount which is proportional to their velocity. The ADCP measures this frequency change, the Doppler shift, and thus constructs vertical current profiles.

In the vessel-mounted configuration the ADCP measures current profiles continuously as the vessel traverses along a transect from one side of a channel to the other. The current profiles, which are initially measured relative to the ADCP, are converted to earth-referenced currents. This can be achieved because the ADCP also has the capability of measuring its own motion relative to the earth using the Doppler shift of echoes received from the bottom of the channel (bottom tracking). Bottom tracking also allows the ADCP to directly measure the distance travelled between individual current profiles along a given transect. The orientation of the transect is assumed to be at a right angle to the channel alignment, which enables the ADCP to calculate long-channel and cross-channel velocities. The long-channel velocity is used to calculate the discharge for each bin. The discharges for the bins are progressively summed as the vessel moves from one side of the channel to the other to give a total discharge through the cross-section.

The current velocity distribution recorded by the ADCP at peak flood and peak ebb at Sites 4, 10, 13 and 15 is shown with the discharge data in Appendix C. The transects started at the left bank (looking downstream). Details of the ADCP transects are shown in Table D in the Data Summary and a list of the filenames is shown in Appendix B.

4.2 Errors

Possible errors associated with measurements of water velocity arise from two sources: determining current speed and determining current direction. The standard deviation in current speed measured by an ADCP is ± 1.3 cm/s while the error in direction is ± 2°.

5. Discharge Data

The discharge at any time is calculated using the following equation:

$$\mathbf{Q(t)} = \sum_{\mathbf{i=1}}^{\mathbf{N}} \mathbf{A_i(t).V_i(t)}$$

where **Q(t)** is the discharge at time t, **N** is the number of metering areas in the cross-section, $\mathbf{A_i(t)}$ is the cross-sectional area of metering area i at time t, and $\mathbf{V_i(t)}$ is the depth-averaged velocity at metering area i at time t. A bottom tracking ADCP measures both velocity and area and calculates cumulative discharge as the vessel moves across the metering section.

The tidal prisms at Sites 4, 10, 13 and 15 are shown in Table 5.1.

Table 5.1 Tidal Prisms

Site No.	Site Name	Ebb ($m^3 \times 10^6$)	Flood ($m^3 \times 10^6$)
4	Merimbula Lake Bridge	2.31	2.05
10	Pambula River Downstream	3.19	3.75
13	Pambula River Upstream	0.34	0.34
15	Yowaka River	0.15	0.15

The discharge at Merimbula Lake Bridge is shown in Figure 5.1. A comparison of discharge between the three sites in Pambula Lake is shown in Figure 5.2.

Composite plots of the tidal discharge rate and the water level for all sites are shown in Appendix C. The nearest water level has been included so that discharge rates can be related to the tidal stage. The total ebb and flood discharge volumes are calculated through integration of the discharge curve above and below the zero discharge line. This calculation assumes that the zero crossing of the discharge curve represents full reversal of the tide.

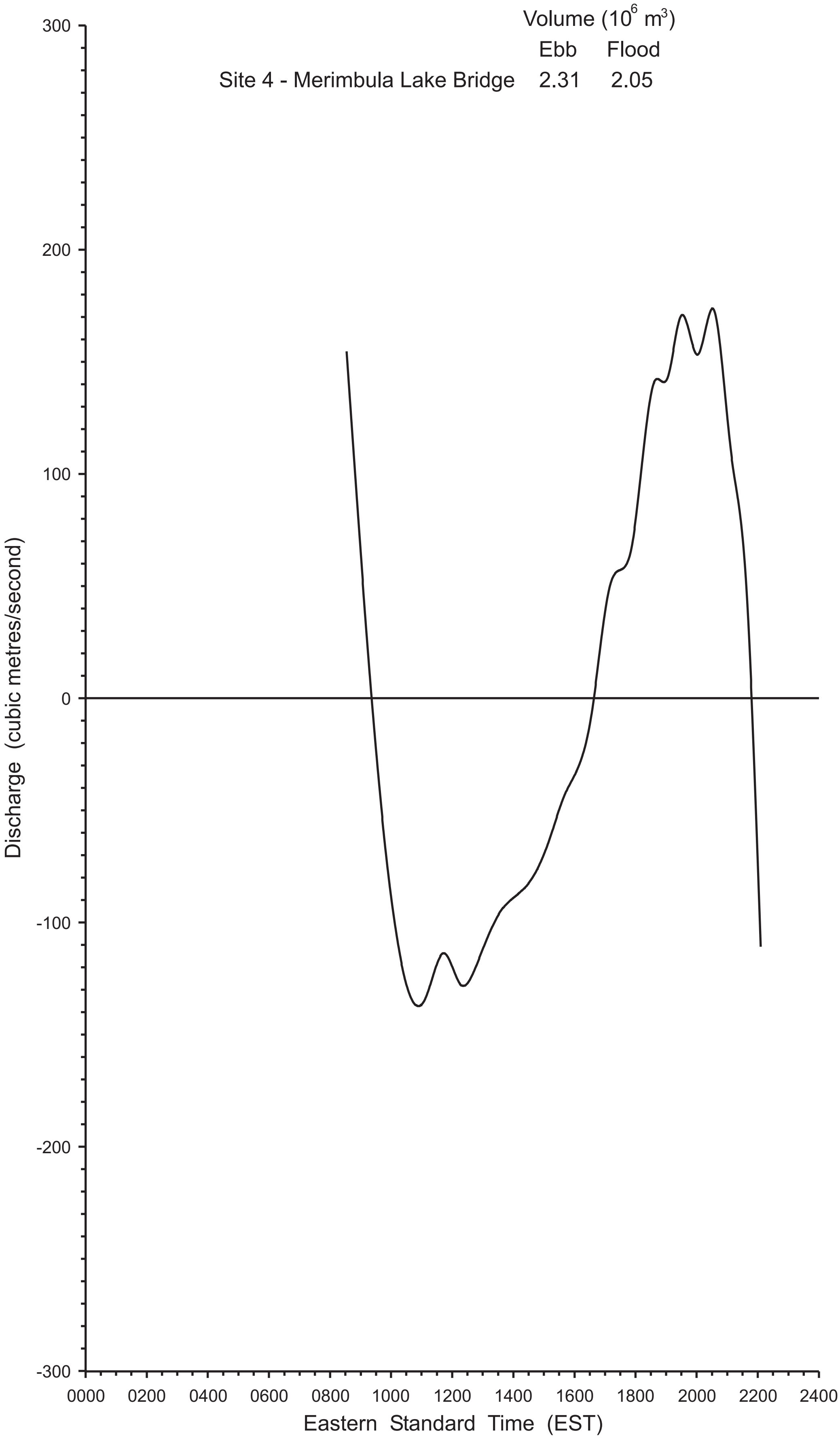
Contours of long-channel velocities at peak flood and ebb discharge at Sites 4, 10, 13 and 15 are shown in Appendix C, alongside the relevant current speed distribution stick plots.

The tidal discharge is a function of channel cross-sectional area and tidal velocity, thus the possible errors in its calculation can be grouped according to these two variables. The use of an ADCP reduces the sources of errors in discharge calculations as measurements of cross-sectional areas are taken simultaneously with the velocity measurements. However, there are some other aspects to be considered.

The ADCP's profiling range is limited at the top, bottom and sides of the channel which results in shadow zones where no data are available. The bottom part of the water column (usually 15% of the water depth) is contaminated by 'side-lobe' interference (RDI 1989) due to strong reflections from the channel bed. The top part of the water column is lost due to the immersion depth of the ADCP transducers, a blanking period to allow the transducer to stop ringing after transmission and the duration of the transmit pulse (RDI 1989). The sides of the channel are lost due to the limitations on how close to the banks the vessel can manoeuvre. To estimate the discharge in the top and bottom zones a one sixth power curve is fitted to the measured data. This curve is then used to extrapolate discharge values for the missing top and bottom layers (Simpson and Oltman 1990). Discharge at the sides of the channel can also be extrapolated using an empirical method described in Simpson and Oltman (1990). Pollard (1992) found that typically, of the total discharge, extrapolation in the top layer accounted for 15%, in the bottom layer for 14% and at the sides for 2%.

Therefore, the total error in discharge calculations when using ADCP data is considered to be in the order of $\pm$ 5%.

It was noted by the field crew collecting the ADCP data at Site 10 that there was a large amount of red calcareous macro-alga present in the water, particularly on the flood tide. This was most likely to be *Jania micrarthrodia*, a species commonly called cornflake weed. It is possible that this algae may have interfered with the ADCP's acoustic signal and may be the source of the discrepancy between the ebb and flood tide volumes measured at this location.



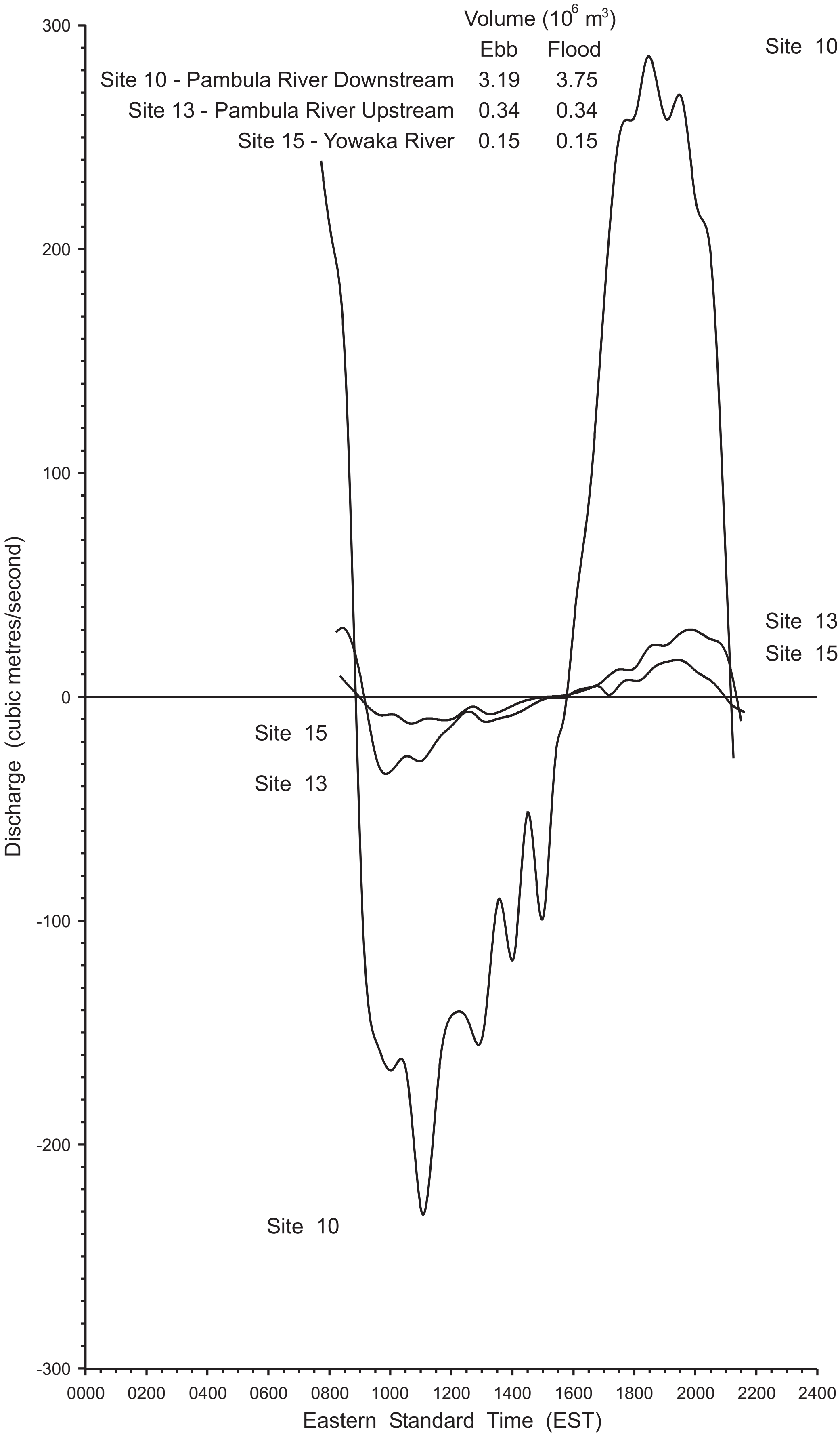
NSW Department of Commerce
MANLY HYDRAULICS LABORATORY

DISCHARGE MERIMBULA LAKE
SITE 4
25 OCTOBER 2003

MHL Report 1290

Figure 5.1

DRAWING 1290-5-01.CDR



NSW Department of Commerce

MANLY HYDRAULICS LABORATORY

COMPARISON OF DISCHARGE PAMBULA LAKE
SITES 10, 13 AND 15
25 OCTOBER 2003

MHL Report 1290

Figure 5.2

DRAWING 1290-5-02.CDR

6. Water Quality Data

Spatial variations in water quality during the short-term intensive data collection program were investigated by undertaking water quality profiles at twenty-nine selected sites in Merimbula Lake on 27 and 30 October 2003; twelve selected sites in Pambula Lake on 27 and 28 October 2003; and eight selected sites in Back Lagoon on 26 October 2003. The general aim was to do one set of profiles during high water slack and the other at low water slack, except on Back Lagoon where only one set was done because the entrance was closed. Density, temperature, salinity, dissolved oxygen, pH, backscatterance, chlorophyll-a and PAR profiles were measured with a Sea-bird Seacat SBE25-03 water quality profiler. The locations at which these profiles were taken are shown in Figures 6.1 and 6.2. The MGA coordinates of each location are listed in Tables 6.1 to 6.3. Summaries of the maxima and minima recorded on the high water and low water runs are shown in Tables 6.4 to 6.9.

Table 6.1 Location of Water Quality Profiling Stations - Merimbula Lake - 27 and 30/10/2003

Station Number	Site Location MGA 56		Distance
	Easting	Northing	(km)
1	760481	5912973	0.19
2	759861	5913520	1.05
3	759178	5912821	2.06
4	758543	5912488	2.75
5	758048	5912470	3.29
6	757542	5912694	3.96
7	757174	5912831	4.35
8	756782	5913726	5.32
9	757667	5913044	1.86
10	757522	5913361	2.28
11	757215	5913439	2.61
12	756745	5913779	3.43
13	756024	5914153	4.40
14	756362	5913258	4.14
15	756385	5912900	4.51
16	756544	5912441	5.01
17	756598	5912040	5.45
18	756890	5911700	5.92
19	757440	5911700	6.53
20	757540	5912135	3.80
21	757771	5911532	6.95
22	757478	5911136	7.43
23	757331	5910659	7.94
24	757620	5910343	8.36
25	757906	5910593	8.75
26	757779	5910977	9.15
27	757813	5911237	9.43
28	757895	5911616	9.82
29	758139	5912034	10.30

Note 1 Distance for Stations 1 to 8 and 20 is measured from the entrance at Merimbula Bay
Note 2 Station 8 not profiled on high water run
Note 3 Stations 9 to 27 were located around the perimeter of Merimbula Lake and only profiled on high water run - distance measured from bridge along shoreline

Table 6.2 Location of Water Quality Profiling Stations - Pambula Lake - 27-28/10/2003

Station Number	Site Location MGA 56		Distance from the Ocean
	Easting	Northing	(km)
1	759667	5906802	0.28
2	758246	5906103	1.97
3	757444	5905222	3.81
4	758103	5904171	5.19
5	758889	5904195	5.99
6	756943	5904625	6.46
7	756653	5905748	7.64
8	756727	5906464	8.46
9	756044	5907366	9.77
10	755744	5905951	8.97
11	755227	5905000	10.13
12	755564	5904457	10.99

Note 1 Stations 9 to 12 not profiled on low water run

Table 6.3 Location of Water Quality Profiling Stations - Back Lagoon - 26/10/2003

Station Number	Site Location MGA 56		Distance from the Ocean
	Easting	Northing	(km)
1	761071	5914010	0.06
2	760917	5914146	0.36
3	760816	5914501	0.73
4	760548	5914199	1.13
5	760123	5914078	1.64
6	759781	5914048	2.00
7	759755	5914371	2.30
8	759565	5913993	3.03

Profiles taken at high water and low water have been used to compile long channel contour plots of density, temperature, salinity, % saturation dissolved oxygen, pH, chlorophyll-a and backscatterance, as shown in Appendix D. PAR contours were not plotted because the values vary throughout the estuary depending on very specific local conditions. Contours of the other parameters were derived by first interpolating the data onto a mesh of rectangular elements with each corner representing a node. The mesh preserves the original position (depth and distance along the estuary) and values of the actual raw data. Contours at each value of interest are then threaded through the mesh again using linear interpolation. The resulting plots effectively represent a snapshot of the physical and chemical properties of the water column along the estuary at the particular time of sampling.

Long channel salinity profiles are shown in Figures 6.3 to 6.6. These profiles are based on the depth-averaged salinity at each of the profile locations on the high and low water runs or, in the case of Back Lagoon, on the only profile run. In Figure 6.6 the intention is to show the depth-averaged salinity data collected around the perimeter of Merimbula Lake at high water. The distance shown on the x-axis is the distance along the northern shoreline upstream (initially) from the Princes Highway bridge, proceeding in an anti-clockwise direction around the lake.

Table 6.4 Water Quality Max. and Min. - Merimbula Lake - High Water - 27 October 2003

Station No.	Time (EST)	Depth (m)	Density (kg/m^3)			Temperature (°C)			Salinity (psu)			Dissolved O_2 (% sat)			pH			Backscatterance (NTU)			Chlorophyll-a (µg/L)			PAR			File Name *.POF
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	1055	3.1	1026.2	1026.3	1026.2	14.87	14.90	14.88	35.30	35.32	35.31	97.73	98.02	97.89	7.88	7.89	7.89	1.04	2.50	1.65	0.00	0.21	0.00	414.4	4514.1	718.8	MPB0110
3	1101	3.2	1026.2	1026.2	1026.2	15.06	15.11	15.07	35.31	35.33	35.31	97.89	98.90	98.38	7.88	7.88	7.88	1.04	2.50	1.78	0.00	0.00	0.00	378.0	1362.7	533.2	MPB0111
4	1108	5.5	1026.2	1026.2	1026.2	15.23	15.25	15.24	35.32	35.33	35.33	101.08	101.38	101.20	7.82	7.85	7.84	1.04	2.01	1.55	0.00	0.00	0.00	516.6	4912.2	1477.3	MPB0112
5	1114	3.2	1026.1	1026.2	1026.1	15.31	15.51	15.36	35.19	35.37	35.32	102.63	103.85	103.08	7.87	7.87	7.87	1.04	2.50	1.69	0.00	0.00	0.00	288.0	1113.4	342.5	MPB0113
6	1119	1.3	1026.1	1026.1	1026.1	15.36	15.39	15.37	35.31	35.33	35.32	104.31	105.43	104.63	7.88	7.88	7.88	1.04	2.01	1.61	0.00	0.00	0.00	823.7	3267.1	1722.9	MPB0114
7	1123	1.3	1025.9	1026.2	1025.9	16.50	17.79	17.42	35.46	35.81	35.67	90.42	93.36	91.46	7.83	7.84	7.84	1.52	2.50	1.75	0.00	0.00	0.00	174.1	651.1	247.9	MPB0115

Note No data collected at Station 1 and Station 8 was not profiled on high water run

Table 6.5 Water Quality Max. and Min. - Merimbula Lake - Low Water - 30 October 2003

Station No.	Time (EST)	Depth (m)	Density (kg/m^3)			Temperature (°C)			Salinity (psu)			Dissolved O_2 (% sat)			PH			Backscatterance (NTU)			Chlorophyll-a (µg/L)			PAR			File Name *.POF
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	
1	0654	2.5	1026.3	1026.5	1026.4	14.22	14.44	14.36	35.20	35.51	35.33	61.92	70.29	64.84	7.75	7.76	7.75	0.55	2.01	1.31	0.00	0.14	0.00	369.8	4717.6	873.7	MPB0213
2	0659	2.9	1026.4	1026.6	1026.5	14.62	14.71	14.67	35.52	35.65	35.57	51.86	54.84	53.26	7.62	7.63	7.62	0.06	2.01	1.20	0.00	0.82	0.01	122.8	683.0	225.5	MPB0214
3	0705	5.1	1026.2	1026.8	1026.5	14.75	15.31	15.09	35.40	35.95	35.67	51.08	58.39	55.29	7.63	7.65	7.64	0.06	2.01	0.89	0.00	0.35	0.00	216.3	5444.4	652.5	MPB0215
4	0711	2.4	1026.1	1026.5	1026.3	15.33	15.70	15.47	35.38	35.75	35.60	58.59	61.22	59.97	7.67	7.69	7.68	0.55	1.52	1.05	0.00	0.00	0.00	101.1	568.4	153.8	MPB0216
5	0725	0.8	1025.9	1026.0	1025.9	16.40	16.42	16.41	35.36	35.38	35.37	57.45	59.19	58.62	7.73	7.74	7.74	0.55	2.01	1.24	0.00	0.03	0.00	512.8	4303.6	1592.6	MPB0217
6	0729	0.7	1026.0	1026.0	1026.0	16.41	16.43	16.42	35.44	35.46	35.45	63.54	63.89	63.71	7.70	7.71	7.70	1.52	2.50	2.09	0.00	0.66	0.14	129.8	627.6	319.8	MPB0218
7	0737	6.8	1025.9	1026.2	1026.1	16.29	16.55	16.42	35.37	35.71	35.59	58.38	70.34	64.52	7.70	7.72	7.71	1.04	2.99	1.51	0.28	2.08	1.02	88.2	5077.3	613.4	MPB0219
8	0751	0.5	1025.8	1026.1	1026.1	15.02	15.24	15.17	34.78	35.22	35.17	80.14	90.08	82.14	7.43	7.46	7.44	0.00	20.57	7.37	4.35	8.02	6.23	50.9	3911.5	1378.1	MPB0220

Table 6.6 Water Quality Max. and Min. - Merimbula Lake - Perimeter at High Water - 27 October 2003

Station No.	Time (EST)	Depth (m)	Density (kg/m^3)			Temperature (°C)			Salinity (psu)			Dissolved O_2 (% sat)			PH			Backscatterance (NTU)			Chlorophyll-a (µg/L)			PAR			File Name *.POF
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	
9	1129	7.2	1025.8	1026.2	1026.0	16.01	18.15	17.06	35.50	35.79	35.67	84.84	88.74	87.65	7.79	7.83	7.82	1.04	2.50	1.66	0.00	2.58	0.90	192.3	3634.4	273.3	MPB0116
10	1136	0.6	1025.6	1025.7	1025.7	17.21	17.30	17.28	35.23	35.32	35.28	89.69	91.95	90.40	7.83	7.84	7.83	0.06	2.50	1.58	0.00	0.00	0.00	765.4	2862.3	1672.5	MPB0117
11	1141	0.6	1025.5	1025.5	1025.5	17.98	18.00	17.99	35.23	35.24	35.24	105.31	105.48	105.38	7.89	7.90	7.90	2.01	2.99	2.45	0.00	0.00	0.00	297.7	1049.8	655.3	MPB0118
12	1146	0.8	1025.5	1025.7	1025.6	17.60	17.78	17.68	35.26	35.38	35.34	102.94	104.28	103.58	7.88	7.89	7.88	2.01	15.20	6.70	0.00	0.20	0.09	200.2	903.0	382.1	MPB0119
13	1153	0.5	1025.6	1025.6	1025.6	18.69	18.70	18.69	35.60	35.62	35.60	89.30	90.30	89.51	7.79	7.80	7.79	3.48	10.32	5.27	0.22	2.88	0.67	461.0	4876.2	3845.8	MPB0120
14	1201	0.4	1024.2	1024.3	1024.3	19.01	19.16	19.04	33.95	34.10	34.06	71.92	74.88	73.69	7.58	7.60	7.59	8.85	66.97	17.52	0.20	0.23	0.22	1788.4	5021.6	4578.5	MPB0121
15	1214	0.7	1020.2	1022.3	1021.5	18.79	18.85	18.83	28.57	31.37	30.29	52.62	72.32	65.27	7.81	7.82	7.82	7.87	111.90	27.63	3.96	6.73	6.01	2141.2	2980.3	2511.9	MPB0122
16	1220	0.5	1016.7	1016.7	1016.7	18.99	19.01	19.00	24.01	24.05	24.03	49.27	50.62	50.10	7.83	7.84	7.83	0.00	37.18	8.13	7.29	11.58	10.35	1939.0	5267.3	4058.0	MPB0123
17	1227	0.5	1015.8	1015.9	1015.8	19.12	19.15	19.13	22.92	23.01	22.93	38.15	38.51	38.27	7.84	7.84	7.84	4.46	25.94	10.56	4.54	7.60	5.39	1261.5	4178.9	2692.7	MPB0124
18	1234	0.5	1015.5	1015.7	1015.7	18.98	19.00	19.00	22.53	22.82	22.72	42.04	43.08	42.43	7.84	7.84	7.84	0.00	42.06	12.60	2.28	3.50	2.85	1387.9	4464.6	2796.3	MPB0125
19	1242	0.5	1014.6	1014.6	1014.6	19.15	19.17	19.16	21.33	21.35	21.34	37.93	38.69	38.22	7.84	7.85	7.85	0.00	36.69	13.06	1.57	8.50	4.13	1146.6	5424.4	4142.9	MPB0126
20	1249	0.5	1015.2	1015.3	1015.2	18.05	18.06	18.06	21.87	21.90	21.89	37.91	38.26	38.10	7.88	7.88	7.88	0.00	62.58	9.77	0.03	0.84	0.37	2435.0	5565.8	4261.5	MPB0127
21	1256	0.7	1014.9	1014.9	1014.9	17.37	17.38	17.38	21.27	21.29	21.28	37.26	37.72	37.50	7.84	7.85	7.85	1.52	2.01	1.56	0.07	0.55	0.21	279.7	4564.1	863.2	MPB0128
22	1302	0.5	1012.5	1012.6	1012.6	17.85	17.86	17.85	18.25	18.41	18.31	36.54	37.84	37.26	7.94	7.95	7.94	1.52	2.01	1.97	0.00	0.00	0.00	721.7	1996.8	1228.8	MPB0129
23	1306	0.4	1006.9	1008.4	1007.4	18.07	18.10	18.08	10.94	12.94	11.62	45.07	45.33	45.22	7.94	7.95	7.94	0.00	124.11	39.03	0.00	0.58	0.13	2480.2	5606.8	3675.6	MPB0130
24	1310	0.5	1012.2	1012.3	1012.3	19.38	19.40	19.39	18.30	18.41	18.35	37.59	37.74	37.69	7.87	7.88	7.87	7.87	9.83	8.97	2.32	3.98	2.93	217.1	1129.8	749.1	MPB0131
25	1314	0.5	1012.3	1012.4	1012.4	19.12	19.15	19.13	18.40	18.52	18.45	34.18	34.35	34.31	7.88	7.89	7.89	2.50	52.81	27.53	3.20	4.63	4.08	1855.4	4351.3	2733.0	MPB0132
26	1320	0.3	1012.9	1012.9	1012.9	16.86	16.86	16.86	18.51	18.51	18.51	48.43	48.43	48.43	7.83	7.83	7.83	19.11	19.11	19.11	2.66	2.66	2.66	1896.7	1896.7	1896.7	MPB0133
27	1328	0.6	1013.1	1013.3	1013.1	18.04	18.06	18.05	19.01	19.32	19.13	40.14	49.08	47.96	7.95	7.95	7.95	0.00	148.53	20.71	0.30	0.66	0.46	1561.1	5190.5	3689.1	MPB0134
28	1334	0.3	1013.1	1013.8	1013.5	18.24	18.26	18.25	19.15	20.05	19.65	53.04	54.06	53.46	7.90	7.90	7.90	1.04	3.48	2.08	0.86	0.93	0.90	383.6	4735.0	2077.0	MPB0135
29	1341	0.3	1013.7	1013.9	1013.9	19.18	19.23	19.19	20.25	20.53	20.40	44.88	49.42	48.27	7.96	7.97	7.97	3.48	6.90	4.94	0.44	0.55	0.47	514.7	2947.7	988.9	MPB0136

Table 6.7 Water Quality Max. and Min. - Pambula Lake - High Water - 28 October 2003

Station No.	Time (EST)	Depth (m)	Density (kg/m^3)			Temperature (°C)			Salinity (psu)			Dissolved O_2 (% sat)			pH			Backscatterance (NTU)			Chlorophyll-a (µg/L)			PAR			File Name *.POF
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	
1	1059	4.7	1026.2	1026.3	1026.2	14.99	15.04	15.02	35.29	35.35	35.32	72.56	79.99	74.46	7.91	7.91	7.91	0.55	2.01	1.08	0.00	3.37	0.40	365.7	644.0	420.4	MPB0201
2	1106	2.7	1026.1	1026.2	1026.2	14.90	15.00	14.95	35.19	35.28	35.24	66.73	76.43	73.48	7.89	7.90	7.90	1.04	2.01	1.26	0.00	8.34	0.95	242.3	1270.8	312.3	MPB0202
3	1113	8.5	1026.1	1026.2	1026.2	14.98	14.99	14.99	35.17	35.31	35.27	73.60	78.99	76.40	7.88	7.89	7.89	0.55	2.01	1.05	0.00	5.23	0.48	103.0	1193.9	200.6	MPB0203
4	1121	5.8	1025.7	1026.2	1026.0	15.57	16.06	15.82	35.01	35.40	35.22	67.32	72.45	70.80	7.84	7.86	7.85	2.50	6.90	4.18	0.00	4.00	0.25	14.4	1049.8	119.1	MPB0204
5	1126	5.1	1025.5	1026.1	1025.7	15.95	16.50	16.30	34.79	35.38	35.08	66.62	75.43	70.61	7.85	7.87	7.86	2.01	2.99	2.21	0.00	2.21	0.53	64.6	933.3	152.0	MPB0205
6	1134	1.8	1025.8	1026.1	1025.9	15.45	15.77	15.66	34.98	35.22	35.05	67.69	73.53	69.51	7.85	7.88	7.86	1.52	2.01	1.57	0.00	1.58	0.12	180.6	727.0	236.2	MPB0206
7	1140	7.2	1025.6	1026.0	1025.9	15.69	16.11	15.83	34.80	35.22	35.11	66.65	72.64	69.94	7.84	7.87	7.86	1.04	3.97	1.77	0.00	3.06	0.15	38.5	743.2	126.6	MPB0207
8	1146	1.8	1025.3	1025.4	1025.3	16.36	16.40	16.39	34.58	34.60	34.59	61.70	64.23	62.50	7.82	7.83	7.82	2.01	2.50	2.10	0.00	0.71	0.11	167.8	737.8	211.1	MPB0208
9	1154	0.7	1024.2	1024.2	1024.2	17.32	17.34	17.33	33.32	33.34	33.33	58.62	59.25	59.00	7.79	7.79	7.79	2.01	2.50	2.25	0.41	0.70	0.54	178.7	594.0	278.2	MPB0209
10	1205	1.3	1022.8	1023.0	1022.9	17.49	17.70	17.58	31.65	31.87	31.77	60.16	61.93	61.06	7.75	7.79	7.76	1.52	2.50	2.02	0.86	1.83	1.30	191.6	854.6	288.2	MPB0210
11	1211	2.0	1019.5	1021.2	1020.3	18.25	20.49	19.46	28.24	29.77	28.90	59.40	63.10	60.74	7.69	7.74	7.73	1.52	2.50	1.72	1.08	2.09	1.41	109.2	693.1	178.9	MPB0211
12	1219	0.6	1014.0	1014.0	1014.0	20.78	20.91	20.83	21.07	21.16	21.12	54.60	55.45	55.06	6.96	7.54	7.24	1.52	2.99	2.01	2.89	4.14	3.32	166.0	600.6	364.4	MPB0212

Table 6.8 Water Quality Max. and Min. - Pambula Lake - Low Water - 27 October 2003

Station No.	Time (EST)	Depth (m)	Density (kg/m^3)			Temperature (°C)			Salinity (psu)			Dissolved O_2 (% sat)			pH			Backscatterance (NTU)			Chlorophyll-a (µg/L)			PAR			File Name *.POF
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	
1	1718	3.1	1025.8	1025.8	1025.8	16.30	16.32	16.31	35.13	35.14	35.14	99.45	99.86	99.65	7.88	7.88	7.88	1.52	3.48	2.20	0.09	0.73	0.30	82.6	281.8	145.3	MPB0139
2	1725	1.4	1025.8	1025.8	1025.8	16.28	16.30	16.29	35.11	35.11	35.11	98.12	98.93	98.81	7.86	7.87	7.86	2.01	2.99	2.33	0.08	0.48	0.22	74.8	255.1	88.4	MPB0140
3	1732	5.8	1025.6	1025.8	1025.7	16.41	16.66	16.52	34.95	35.12	35.04	97.15	98.77	98.02	7.86	7.87	7.86	1.52	3.48	2.26	0.22	1.74	0.41	16.3	3149.2	139.7	MPB0141
4	1739	4.4	1025.5	1026.1	1025.8	15.23	17.22	16.32	35.00	35.26	35.14	91.65	98.55	95.68	7.86	7.88	7.87	2.01	3.97	3.00	0.69	2.37	1.02	20.0	2718.8	139.0	MPB0142
5	1745	3.7	1025.4	1026.0	1025.9	15.55	16.82	15.91	34.38	35.23	35.13	86.66	94.75	91.88	7.84	7.87	7.85	2.50	11.29	4.31	0.96	3.02	1.44	17.8	315.7	41.2	MPB0143
6	1752	0.7	1022.6	1022.6	1022.6	18.97	18.97	18.97	31.85	31.85	31.85	86.90	86.91	86.91	7.80	7.80	7.80	2.99	2.99	2.99	0.61	0.64	0.62	60.7	61.3	61.0	MPB0144
7	1758	3.5	1024.0	1026.1	1025.5	16.43	18.95	17.26	33.64	35.58	35.02	64.09	67.97	66.35	7.80	7.84	7.83	1.52	2.50	2.14	6.62	8.86	7.75	15.8	80.8	34.6	MPB0145
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note No data collected at Station 8 due to instrument memory being full and no profiling done at Stations 9 to 12 on low water run

Table 6.9 Water Quality Max. and Min. - Back Lagoon - 26 October 2003

Station No.	Time (EST)	Depth (m)	Density (kg/m^3)			Temperature (°C)			Salinity (psu)			Dissolved O_2 (% sat)			pH			Backscatterance (NTU)			Chlorophyll-a (μg/L)			PAR			File Name *.POF
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	
1	0807	0.6	1015.3	1015.3	1015.3	16.77	16.92	16.83	21.58	21.65	21.61	87.76	88.33	88.06	7.37	7.39	7.38	3.48	3.97	3.53	0.47	0.92	0.61	556.0	1499.3	1308.1	MPB0101
2	0813	1.3	1015.3	1015.4	1015.3	17.55	17.81	17.59	21.75	22.03	21.79	77.59	78.01	77.81	7.33	7.35	7.34	2.99	4.46	3.77	0.35	0.73	0.55	315.7	2033.8	716.1	MPB0102
3	0820	1.9	1015.1	1015.3	1015.3	17.68	18.04	17.82	21.71	21.95	21.90	77.29	77.92	77.59	7.34	7.35	7.34	3.48	5.43	4.04	0.68	0.95	0.82	174.1	1418.9	405.2	MPB0103
4	0827	0.8	1015.1	1015.3	1015.2	17.94	18.03	17.96	21.67	21.95	21.75	76.98	77.49	77.17	7.33	7.34	7.33	3.97	4.94	4.55	1.41	2.09	1.77	123.3	616.2	296.6	MPB0104
5	0833	1.1	1014.8	1015.3	1015.2	19.10	19.27	19.21	21.72	22.36	22.24	70.10	72.52	71.41	7.23	7.26	7.24	3.48	4.94	3.95	1.26	1.61	1.39	71.3	530.0	200.4	MPB0105
6	0839	5.0	1015.2	1016.5	1015.8	17.59	19.80	18.85	22.25	23.39	22.79	1.45	67.55	43.51	6.95	7.23	7.15	2.01	7.38	3.34	1.00	4.33	2.10	$6.7	560.1	$53.4	MPB0106
7	0846	1.7	1014.5	1015.2	1015.0	20.15	20.89	20.37	21.83	22.47	22.30	56.55	62.88	59.93	7.08	7.14	7.12	2.50	4.94	3.46	1.06	1.74	1.33	101.8	541.9	167.9	MPB0107
8	0855	1.0	1014.4	1014.5	1014.4	22.05	22.20	22.12	22.05	22.19	22.12	26.53	29.11	27.98	6.81	6.82	6.81	2.01	2.99	2.70	1.93	2.36	2.16	112.9	729.7	293.0	MPB0108

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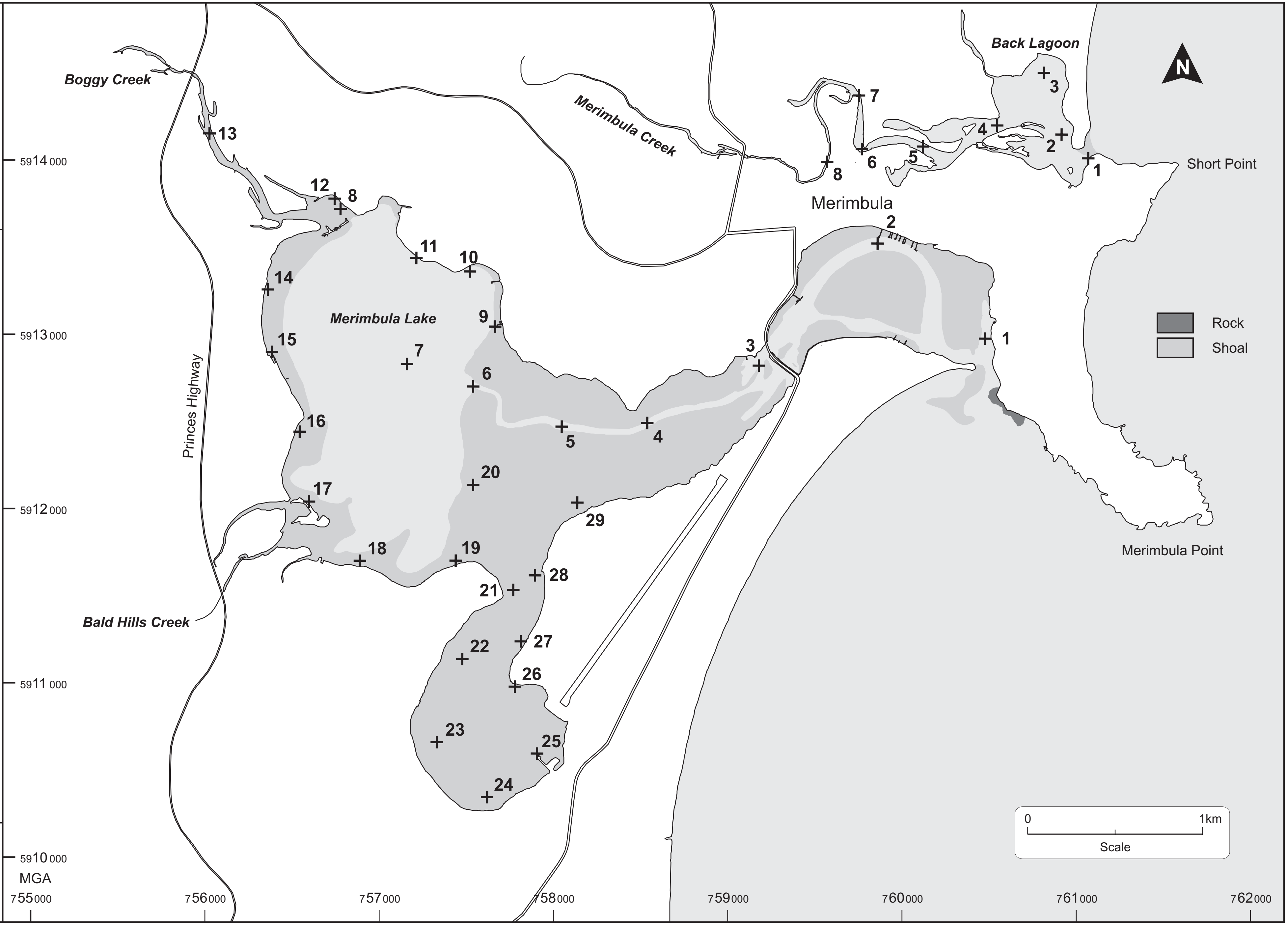
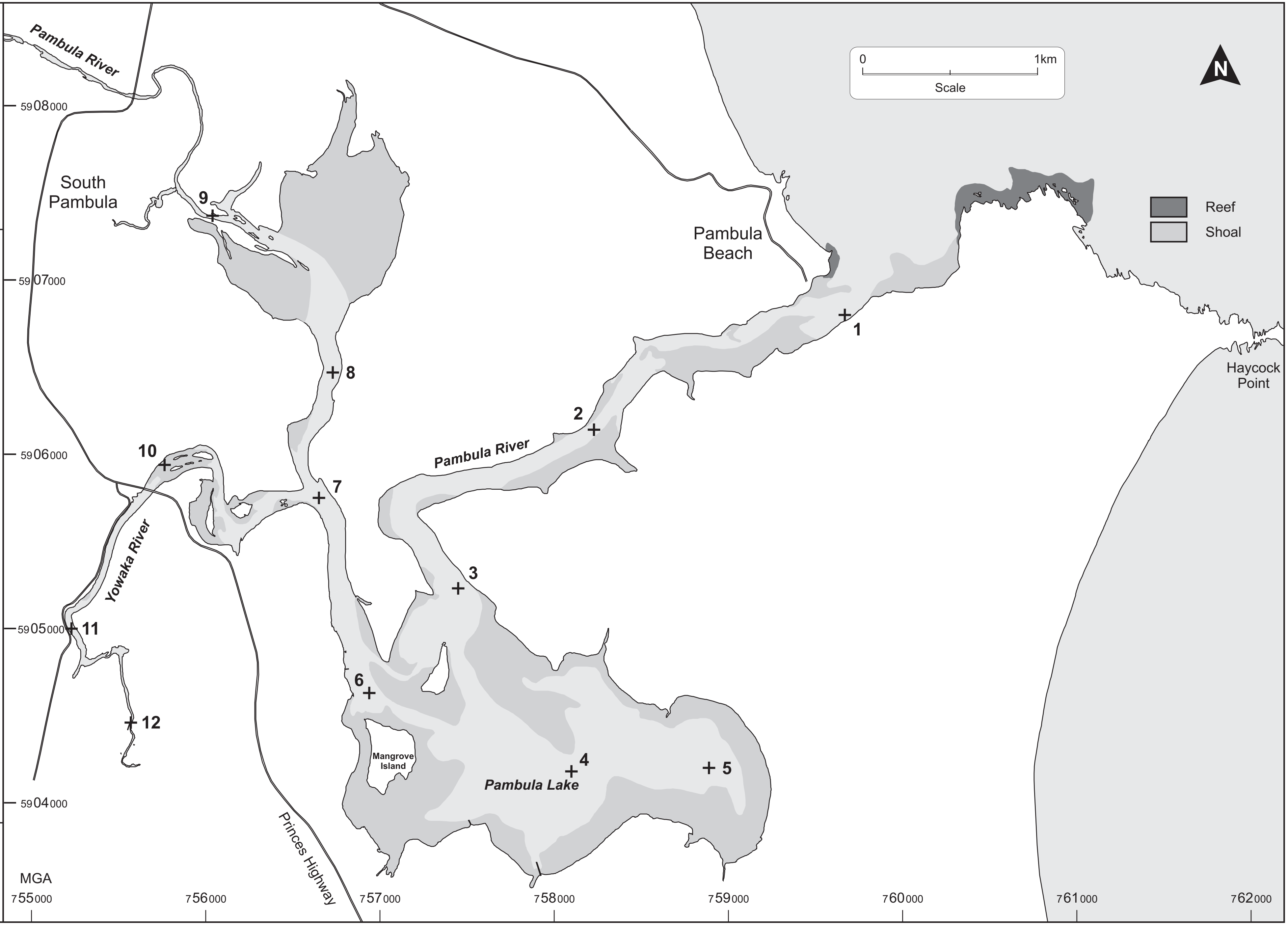
LOCATIONS OF WATER QUALITY PROFILES MERIMBULA LAKE AND BACK LAGOON



MHL Report 1290
Figure 6.1
DRAWING 1290-6-01.CDR



LOCATIONS OF WATER QUALITY PROFILES
PAMBULA LAKE

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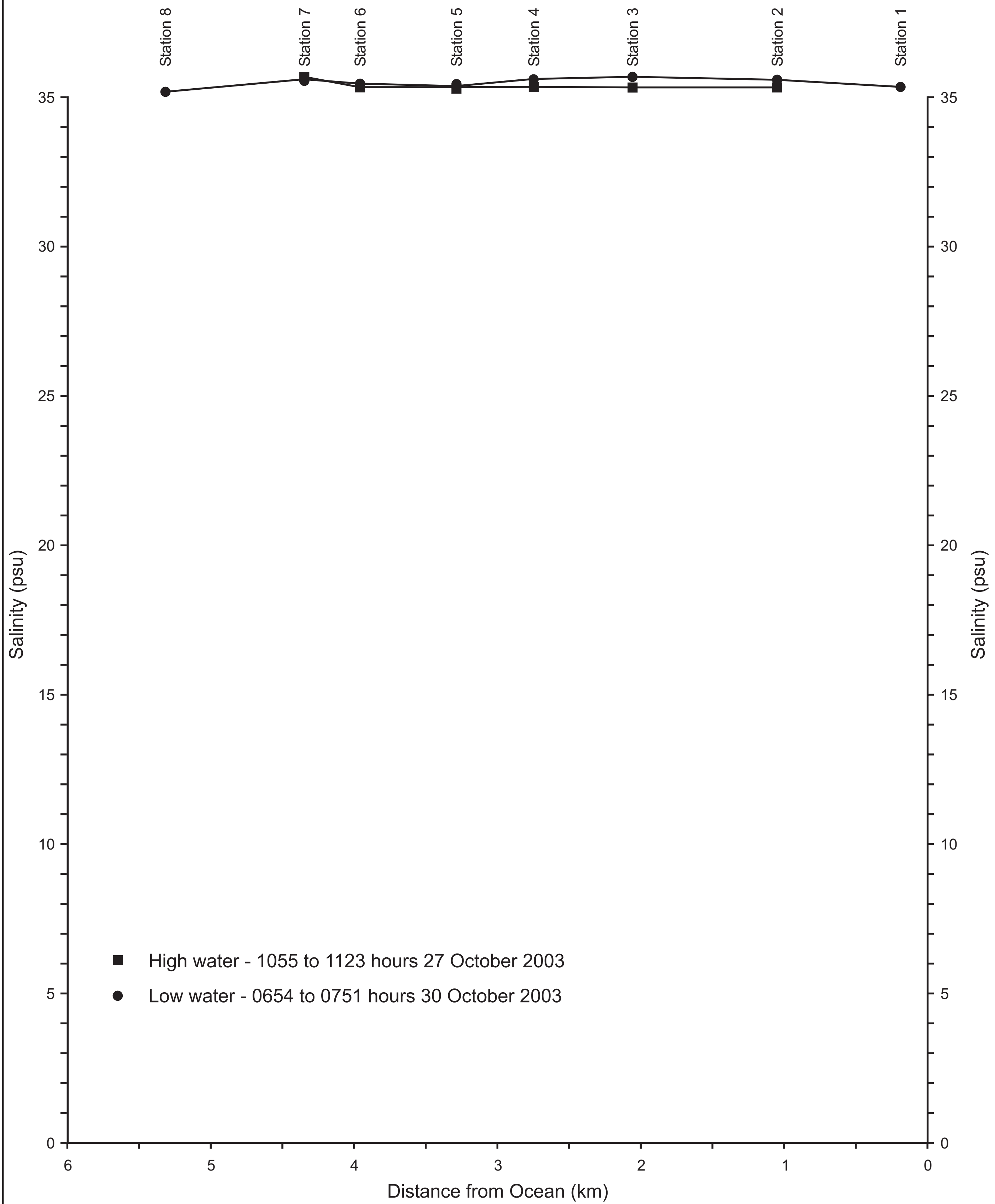
MHL Report 1290
Figure 6.2
DRAWING 1290-6-02.CDR



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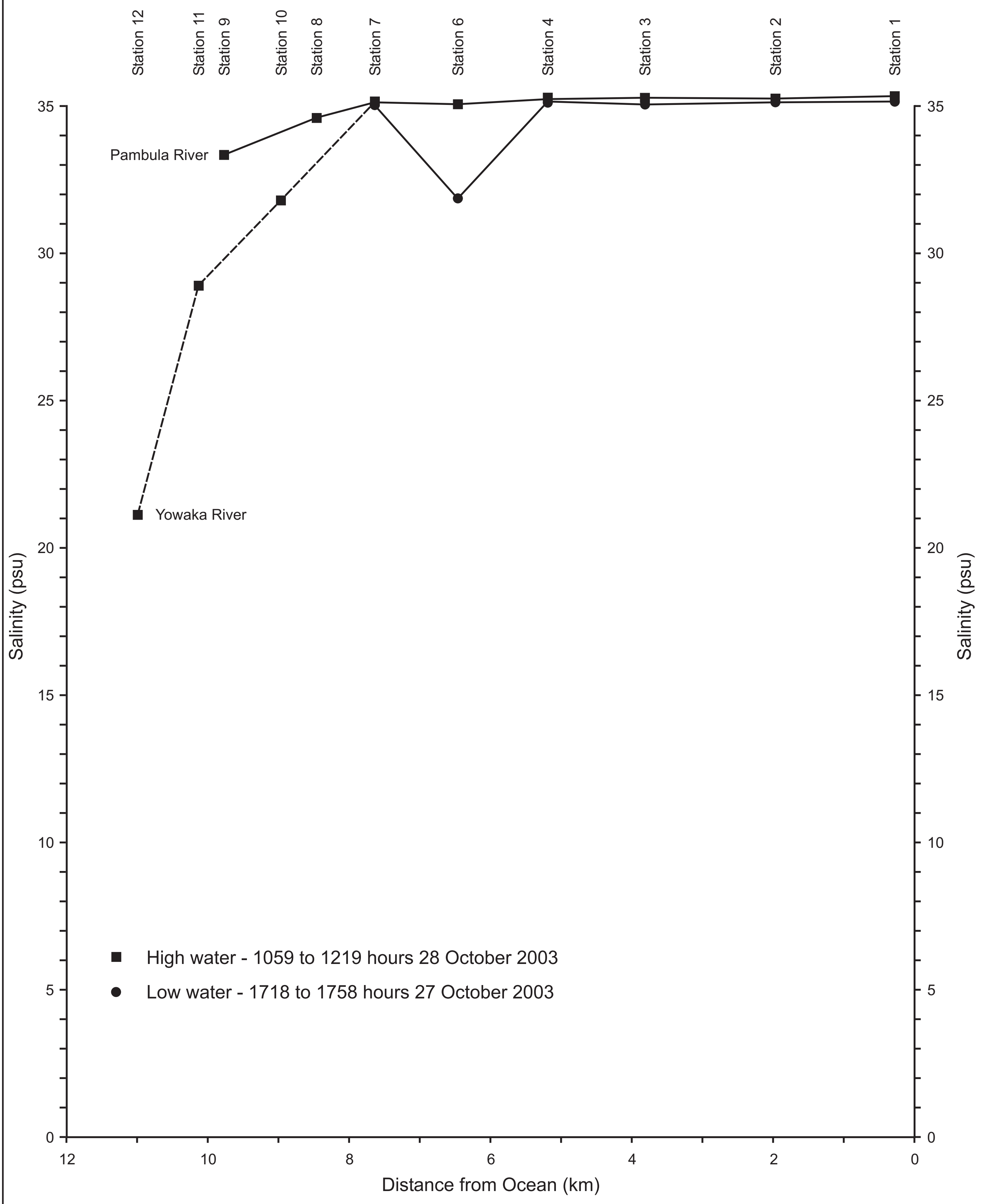
LONG CHANNEL DEPTH AVERAGED SALINITY PROFILES
MERIMBULA LAKE - HIGH AND LOW WATER
27 AND 30 OCTOBER 2003

MHL Report 1290

Figure 6.3

DRAWING 1290-6-03.CDR



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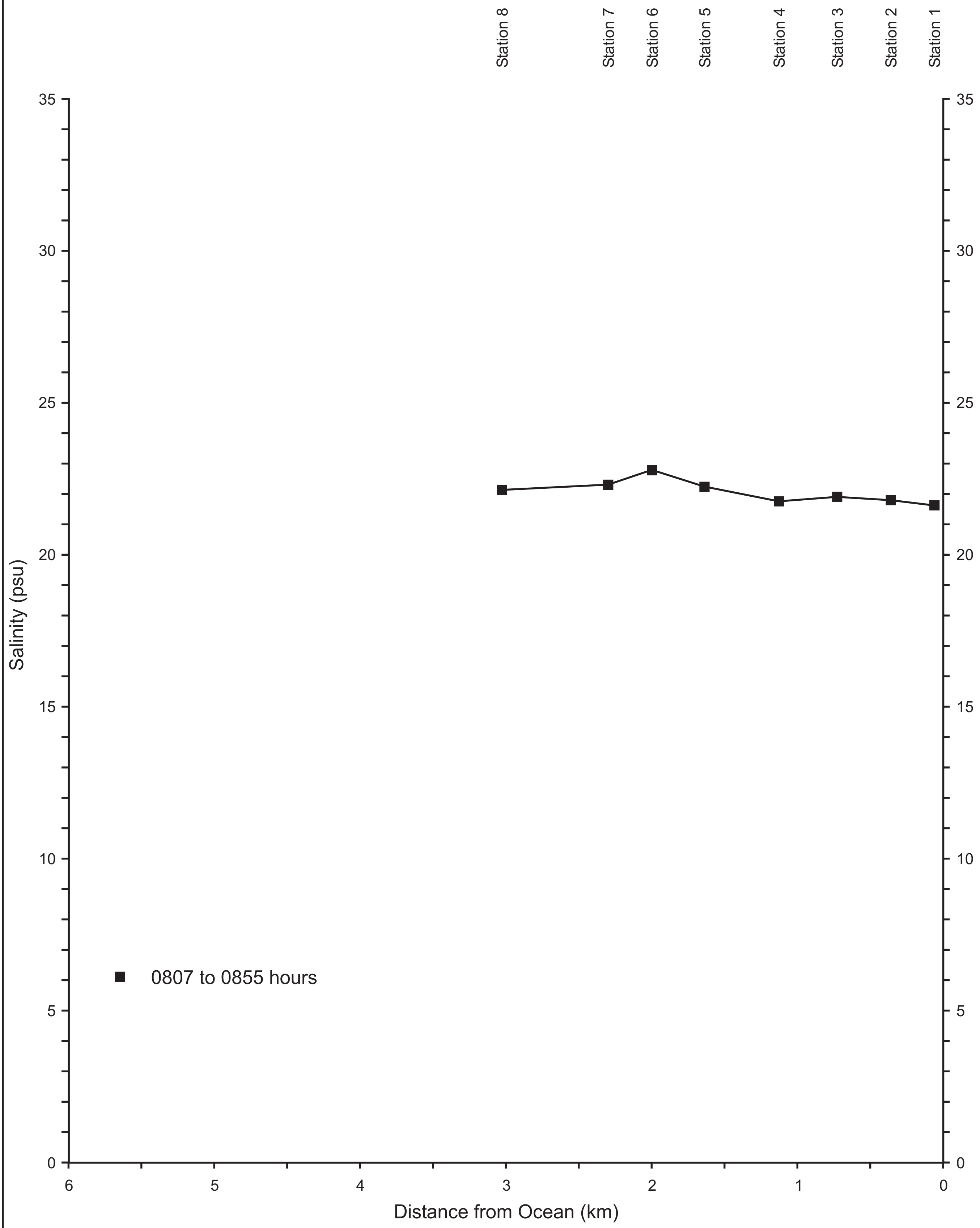
MANLY HYDRAULICS LABORATORY

LONG CHANNEL DEPTH AVERAGED SALINITY PROFILES
PAMBULA LAKE - HIGH AND LOW WATER
27 AND 28 OCTOBER 2003

MHL Report 1290

Figure 6.4

DRAWING 1290-6-04.CDR



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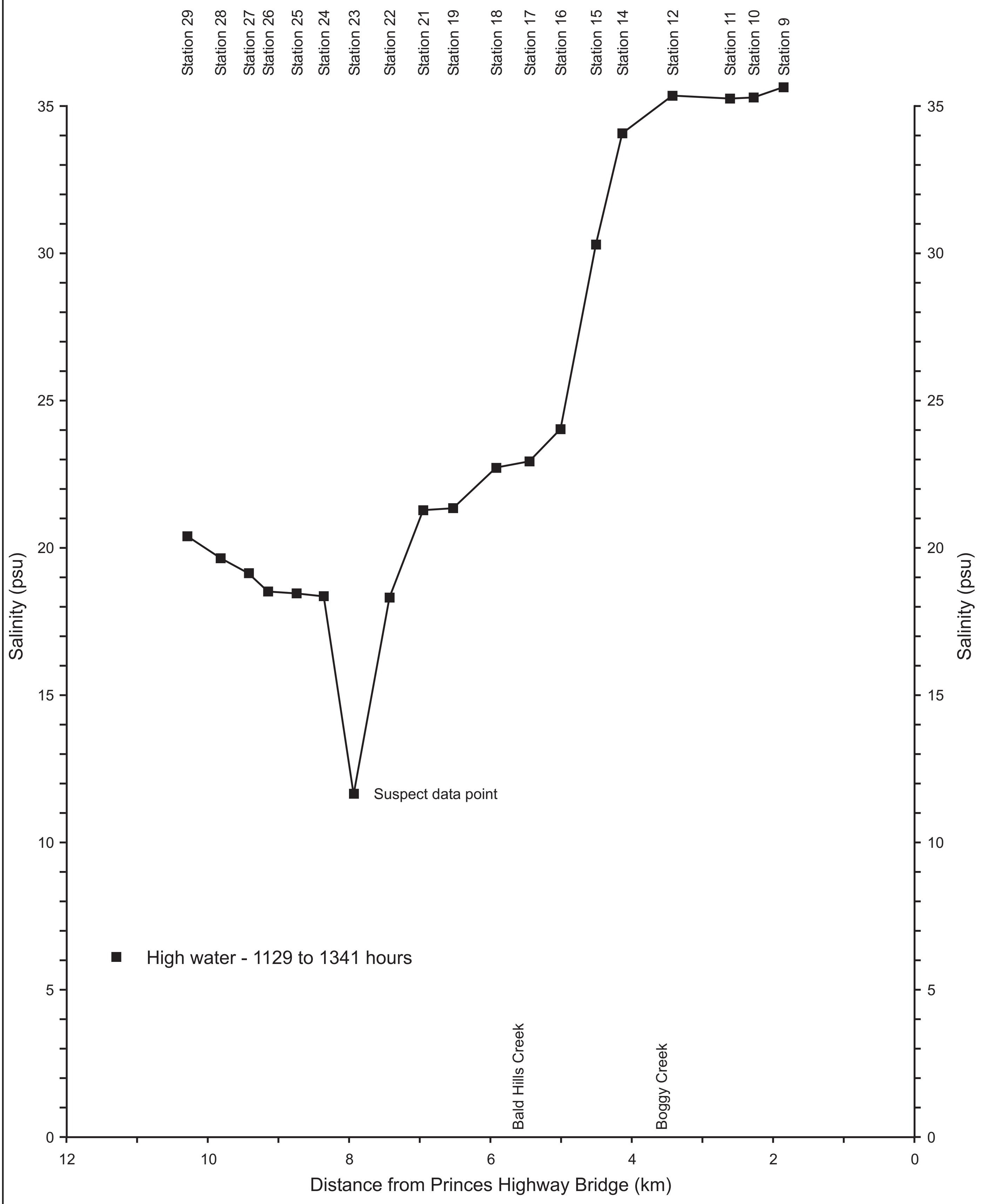
MANLY HYDRAULICS LABORATORY

LONG CHANNEL DEPTH AVERAGED SALINITY PROFILES
BACK LAGOON
27 OCTOBER 2003

MHL Report 1290

Figure 6.5

DRAWING 1290-6-05.CDR



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MANLY HYDRAULICS LABORATORY

PERIMETER DEPTH AVERAGED SALINITY PROFILES
MERIMBULA LAKE - HIGH WATER
27 OCTOBER 2003

MHL Report 1290

Figure 6.6

DRAWING 1290-6-06.CDR

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Appendix A

Water Level Data

Sites 0, 2, 3, 5, 6, 7, 8, 9, 11, 12, 14 and 16

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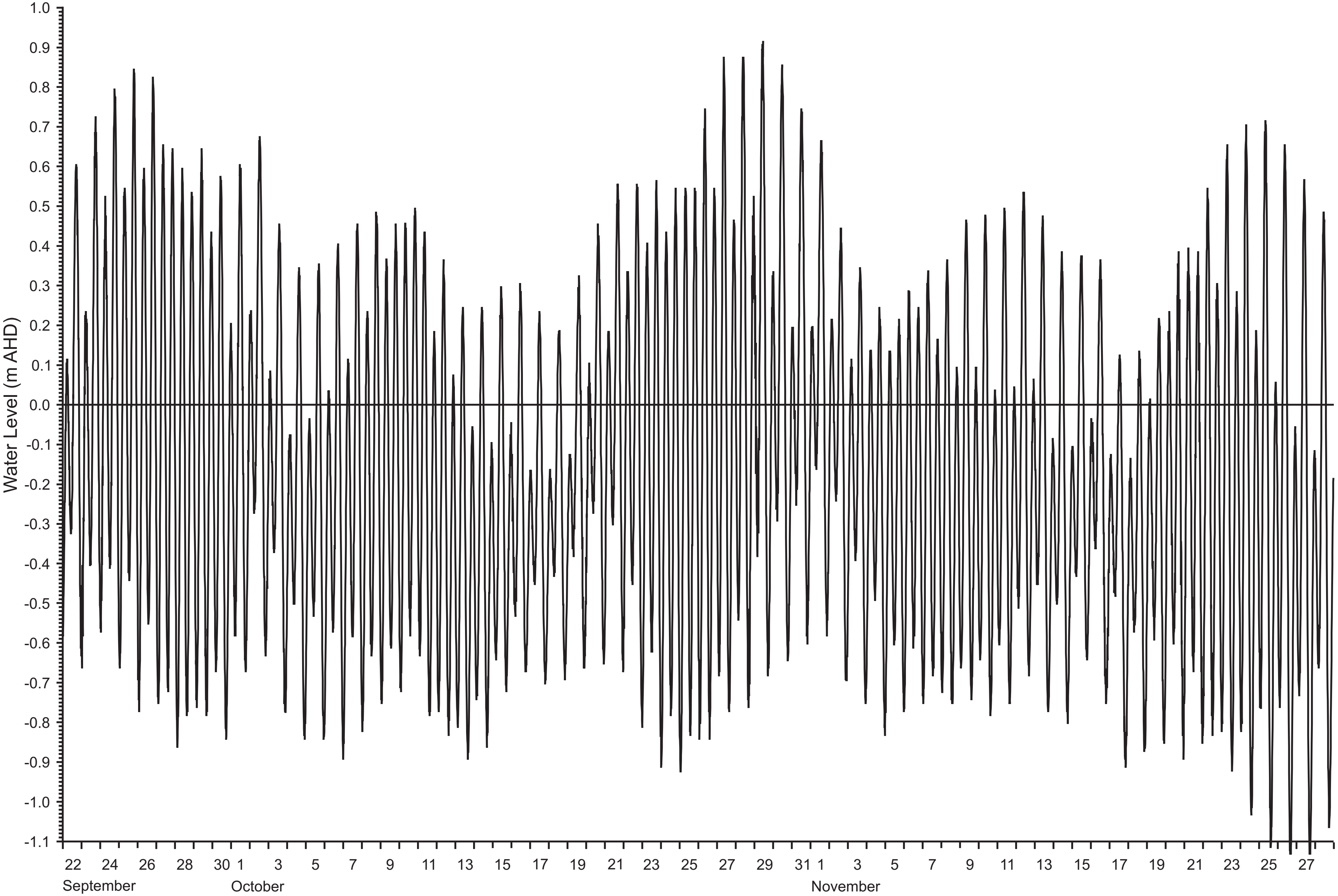
SITE 0 - EDEN
WATER LEVEL DATA
22 SEPTEMBER TO 28 NOVEMBER 2003



MHL Report 1290
Figure A1
DRAWING 1290-A01.CDR

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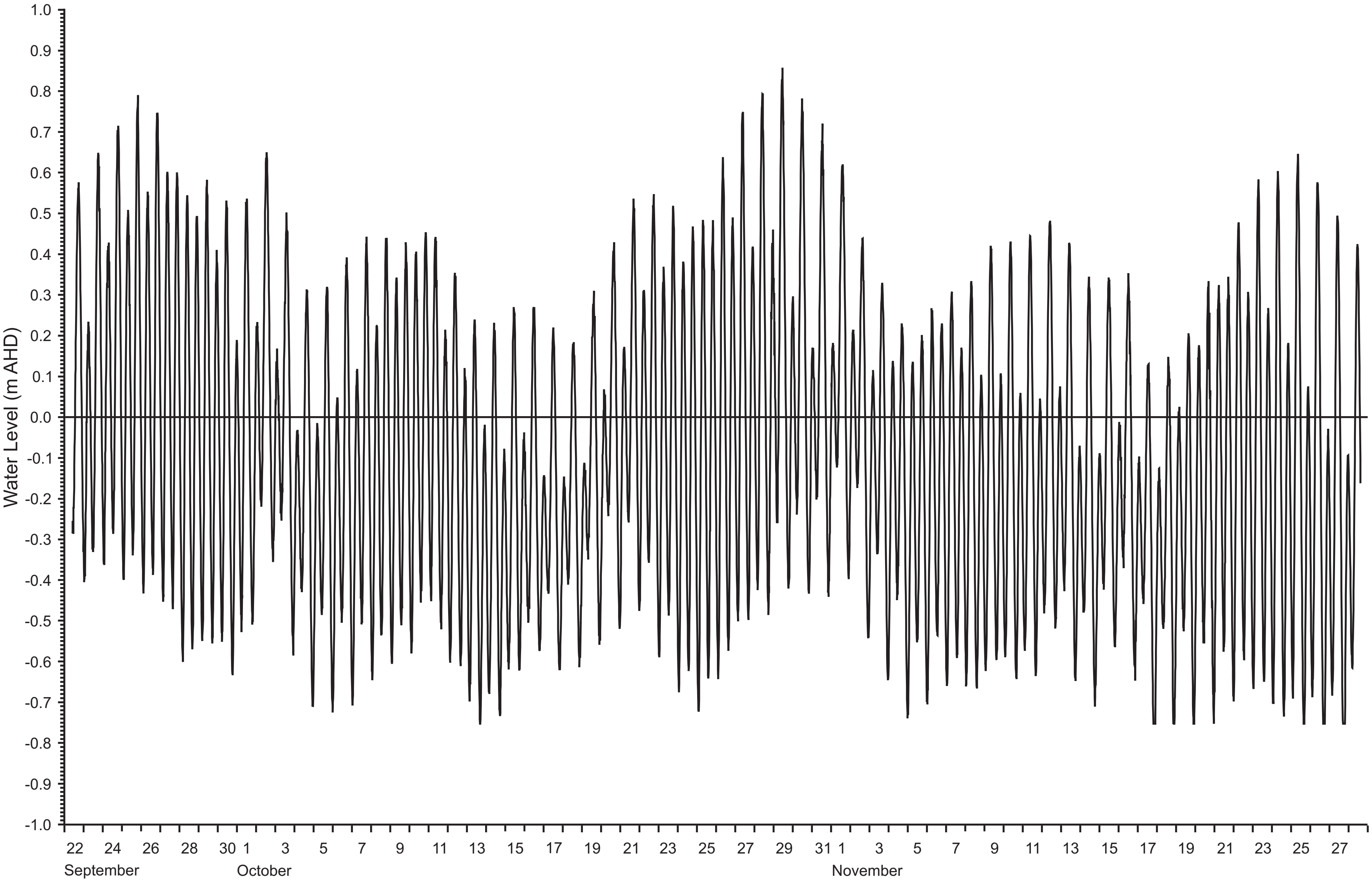
SITE 2 - MERIMBULA LAKE MITCHIES BEACH
WATER LEVEL DATA
22 SEPTEMBER TO 28 NOVEMBER 2003



MHL Report 1290
Figure A2

DRAWING 1290-A02.CDR

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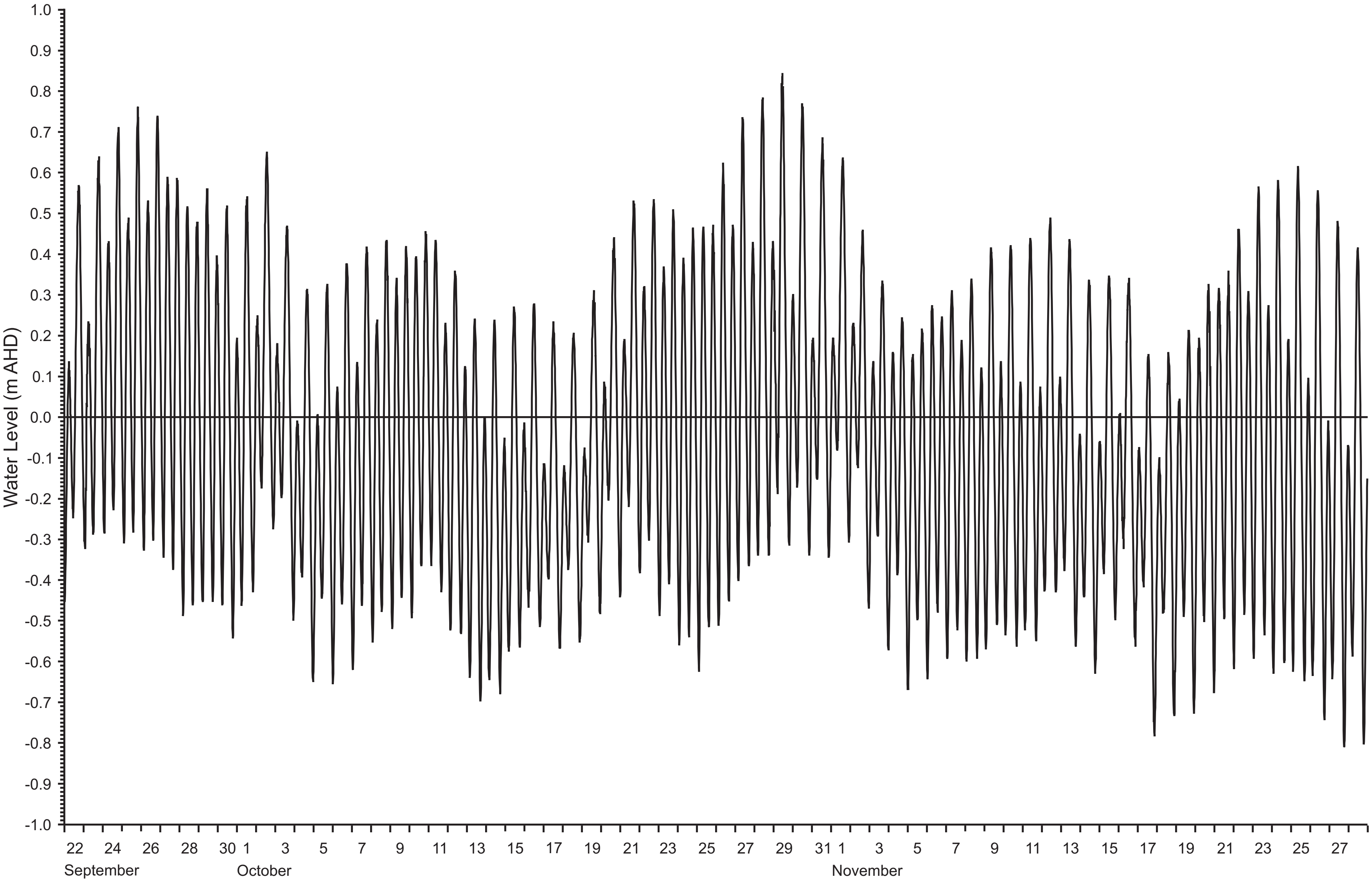
SITE 3 - MERIMBULA WHARF
WATER LEVEL DATA
22 SEPTEMBER TO 28 NOVEMBER 2003



MHL Report 1290

Figure A3

DRAWING 1290-A03.CDR

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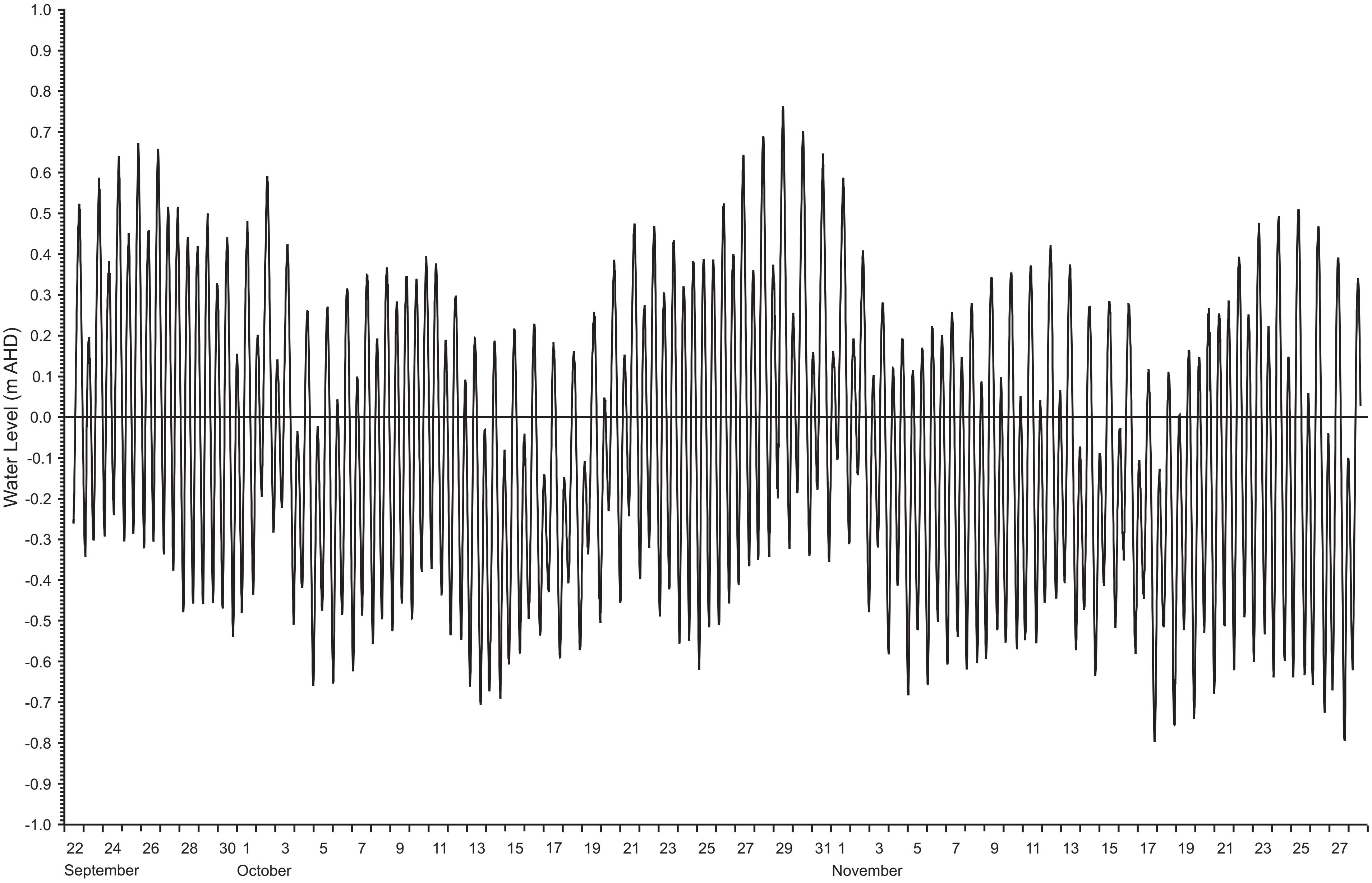
SITE 5 - MERIMBULA LAKE BRIDGE
WATER LEVEL DATA
22 SEPTEMBER TO 28 NOVEMBER 2003



MHL Report 1290
Figure A4
DRAWING 1290-A04.CDR

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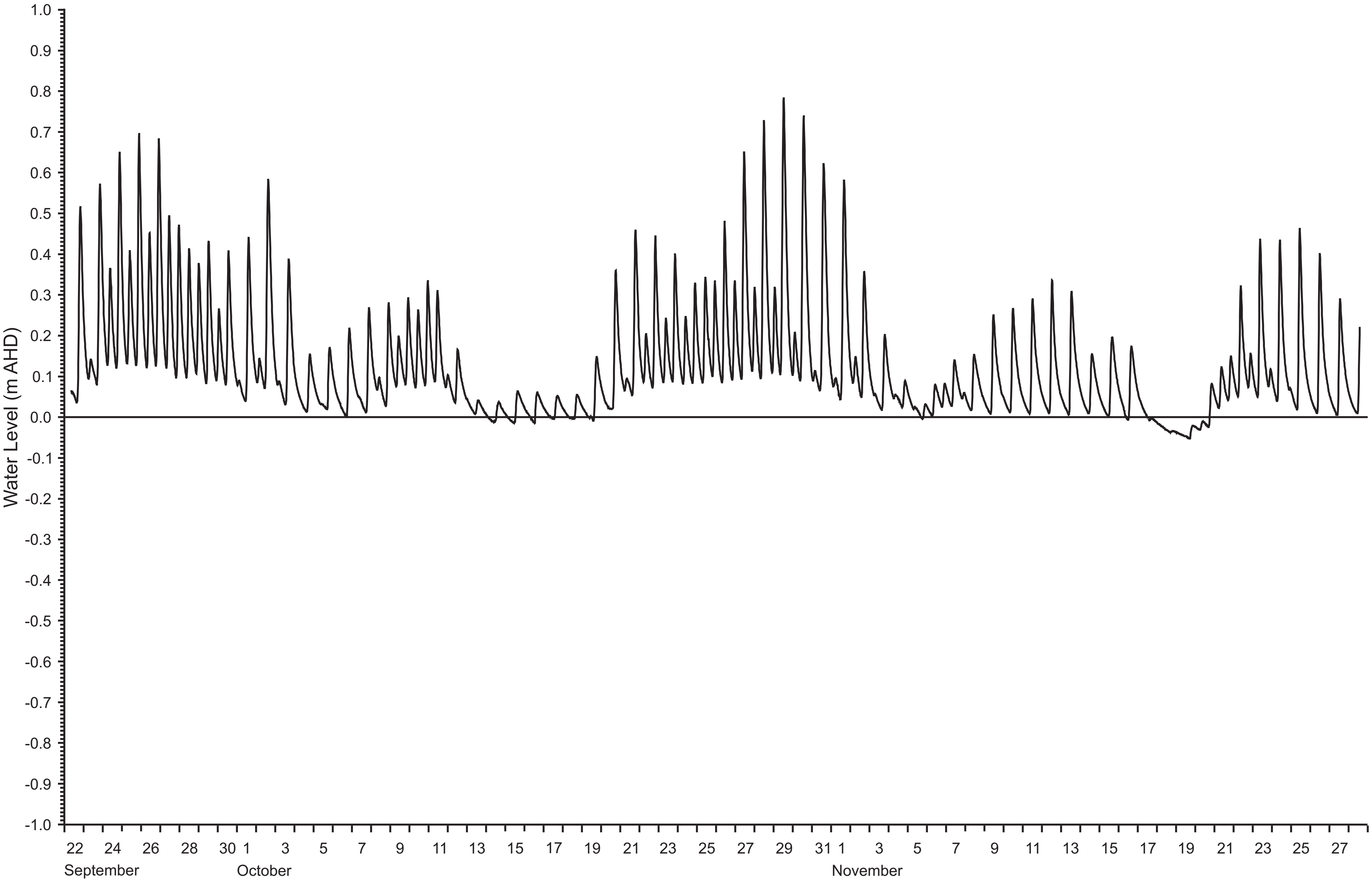
SITE 6 - MERIMBULA LAKE SOUTH
WATER LEVEL DATA
22 SEPTEMBER TO 28 NOVEMBER 2003



MHL Report 1290
Figure A5
DRAWING 1290-A05.CDR

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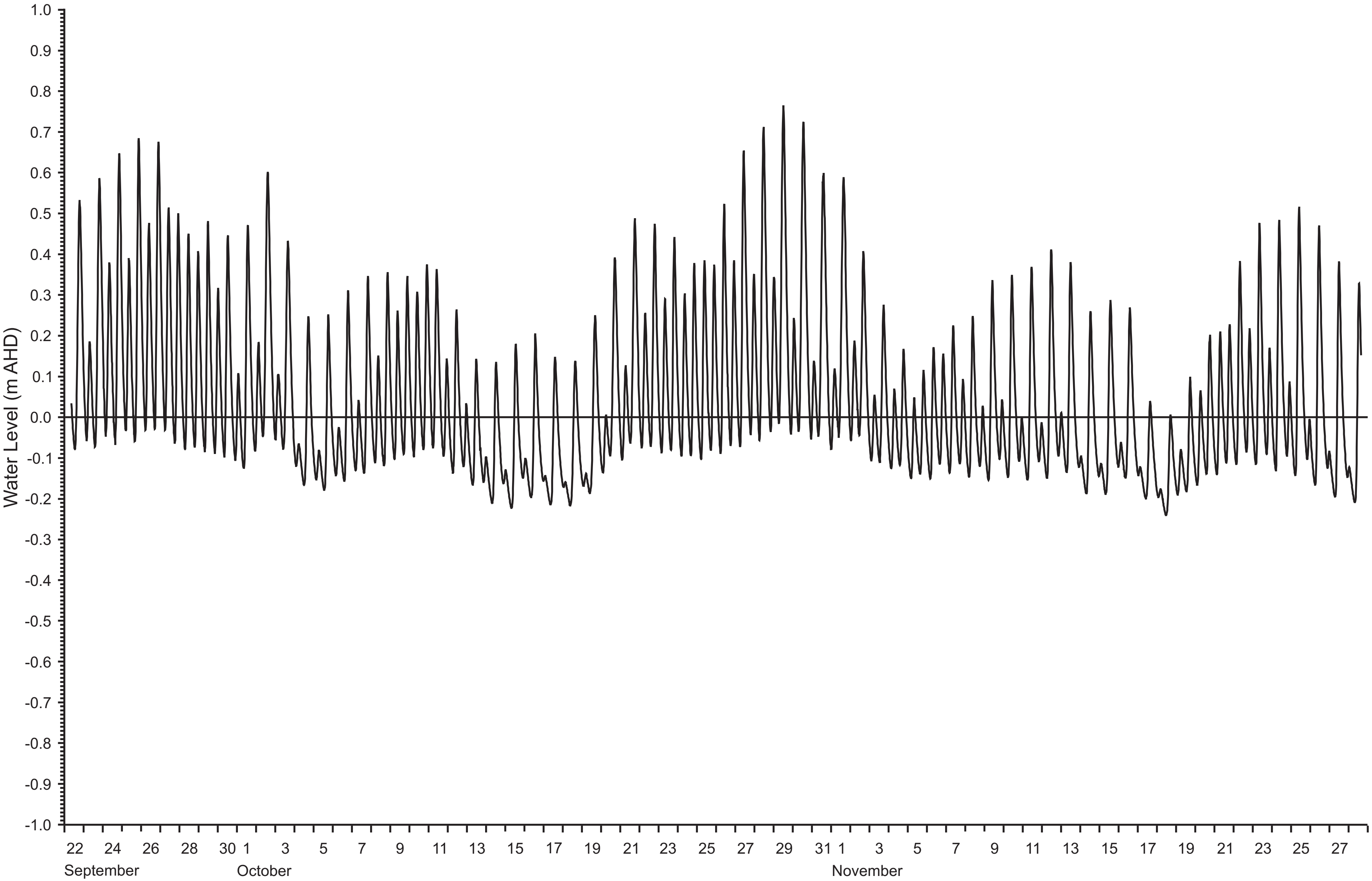
SITE 7 - MERIMBULA LAKE CENTRE

WATER LEVEL DATA

22 SEPTEMBER TO 28 NOVEMBER 2003



MHL Report 1290

Figure A6

DRAWING 1290-A06.CDR

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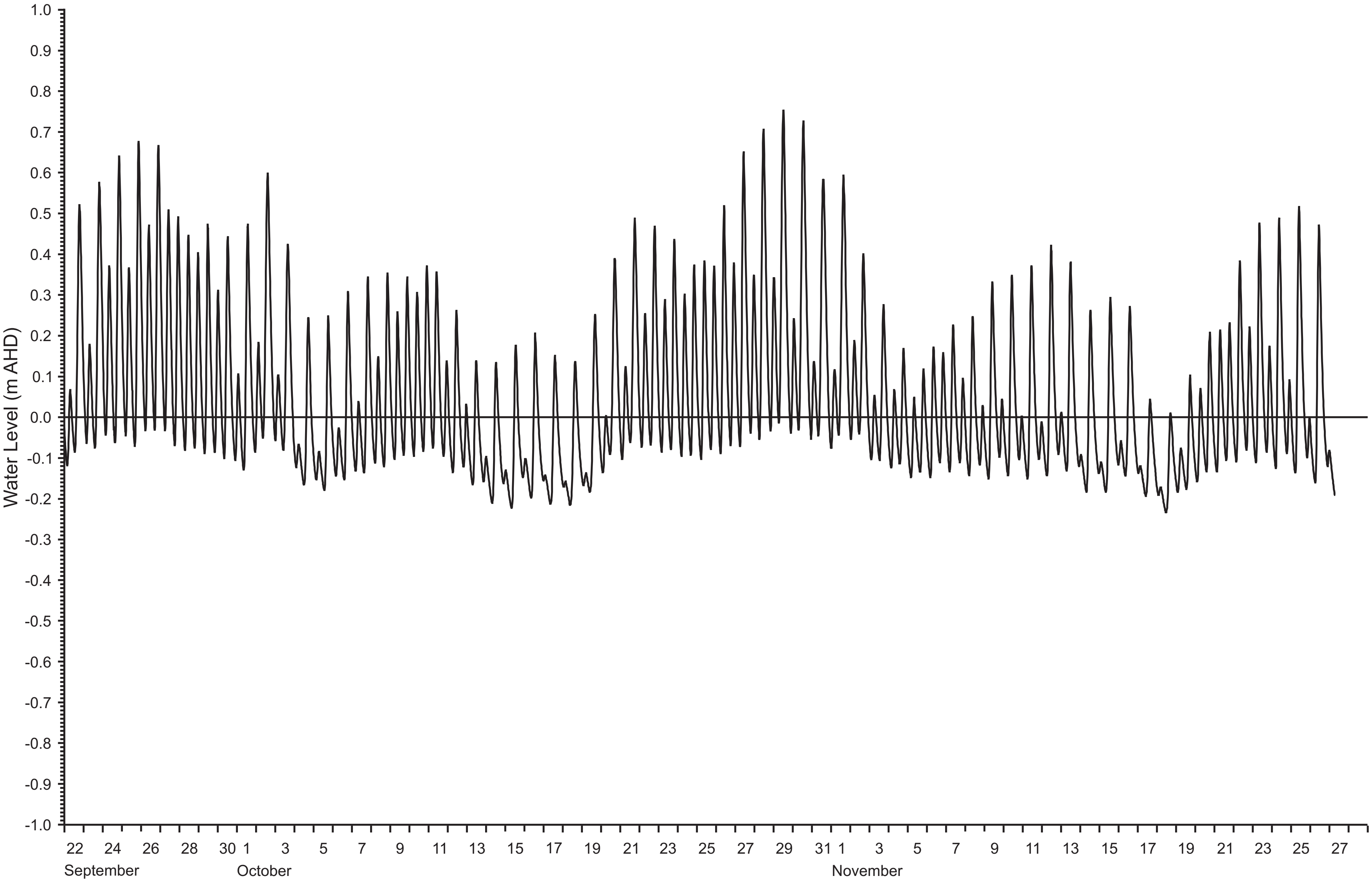
SITE 8 - MERIMBULA LAKE NORTH-WEST
WATER LEVEL DATA
22 SEPTEMBER TO 28 NOVEMBER 2003



MHL Report 1290

Figure A7

DRAWING 1290-A07.CDR

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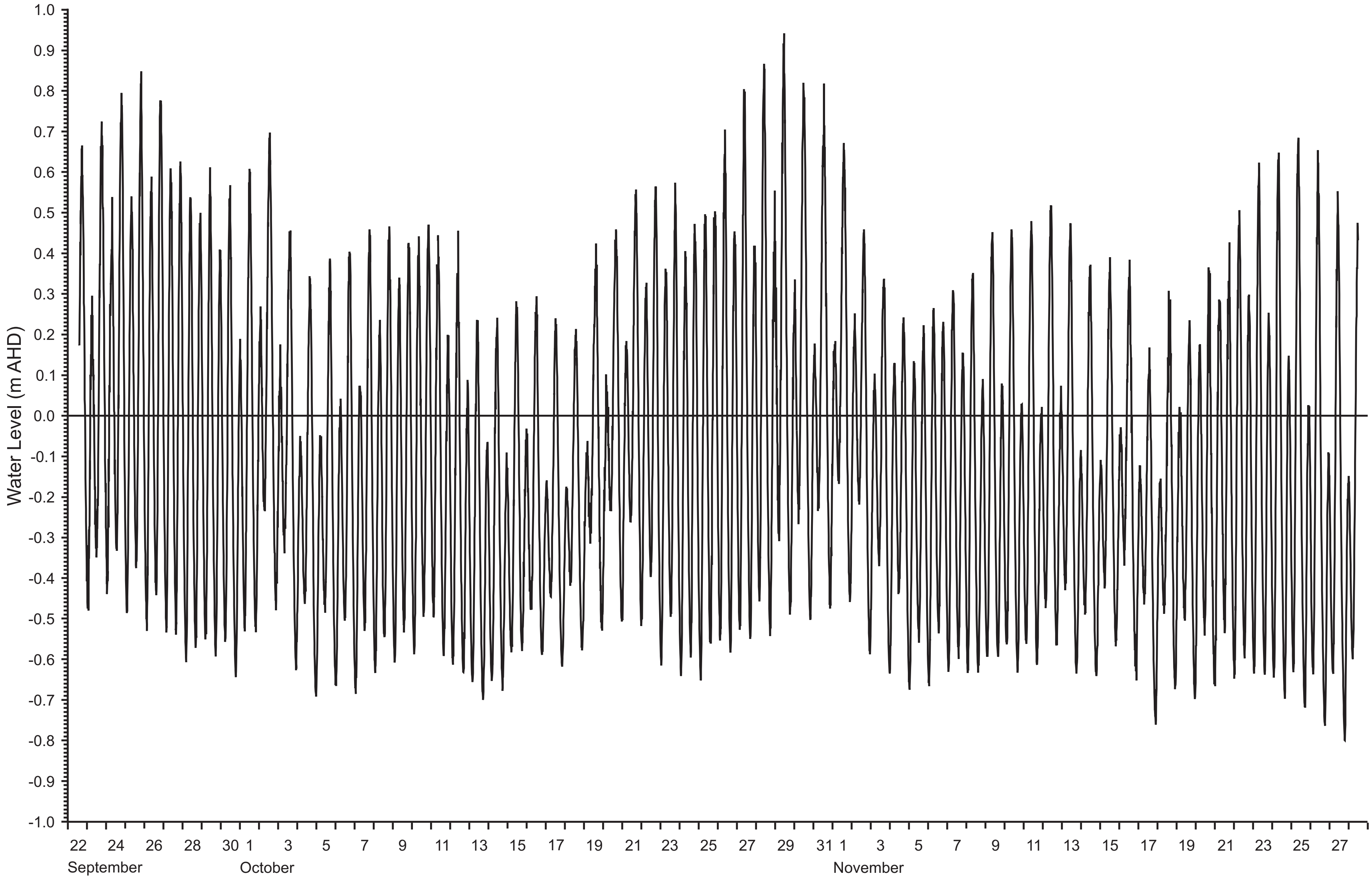
SITE 9 - PAMBULA LAKE ENTRANCE
WATER LEVEL DATA
22 SEPTEMBER TO 28 NOVEMBER 2003



MHL Report 1290
Figure A8
DRAWING 1290-A08.CDR

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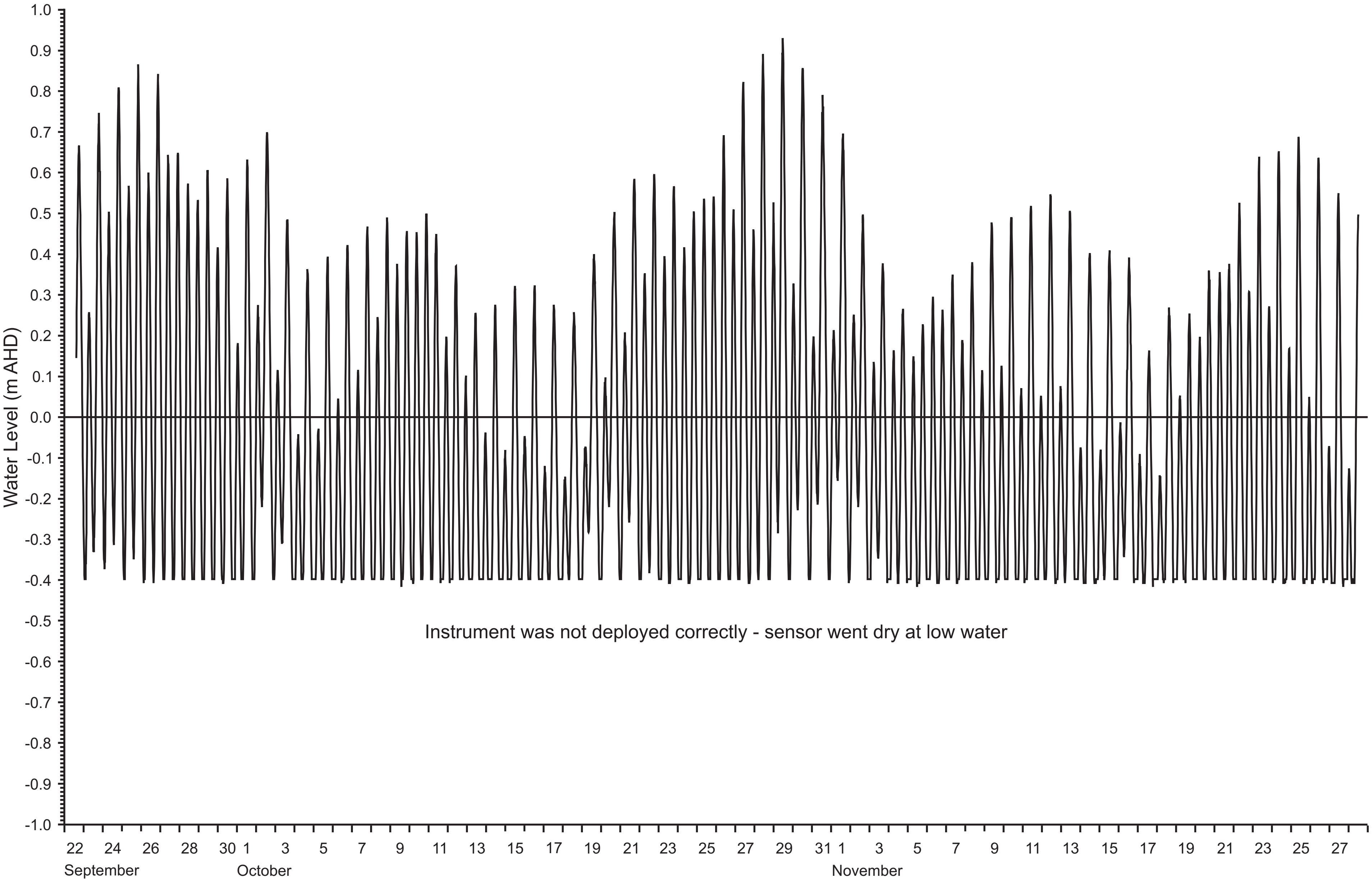
MANLY HYDRAULICS LABORATORY

SITE 11 - PAMBULA LAKE SOUTH-EAST
WATER LEVEL DATA
22 SEPTEMBER TO 28 NOVEMBER 2003



MHL Report 1290

Figure A9

DRAWING 1290-A09.CDR

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MANLY HYDRAULICS LABORATORY

SITE 12 - PAMBULA LAKE NORTH-WEST
WATER LEVEL DATA
22 SEPTEMBER TO 28 NOVEMBER 2003

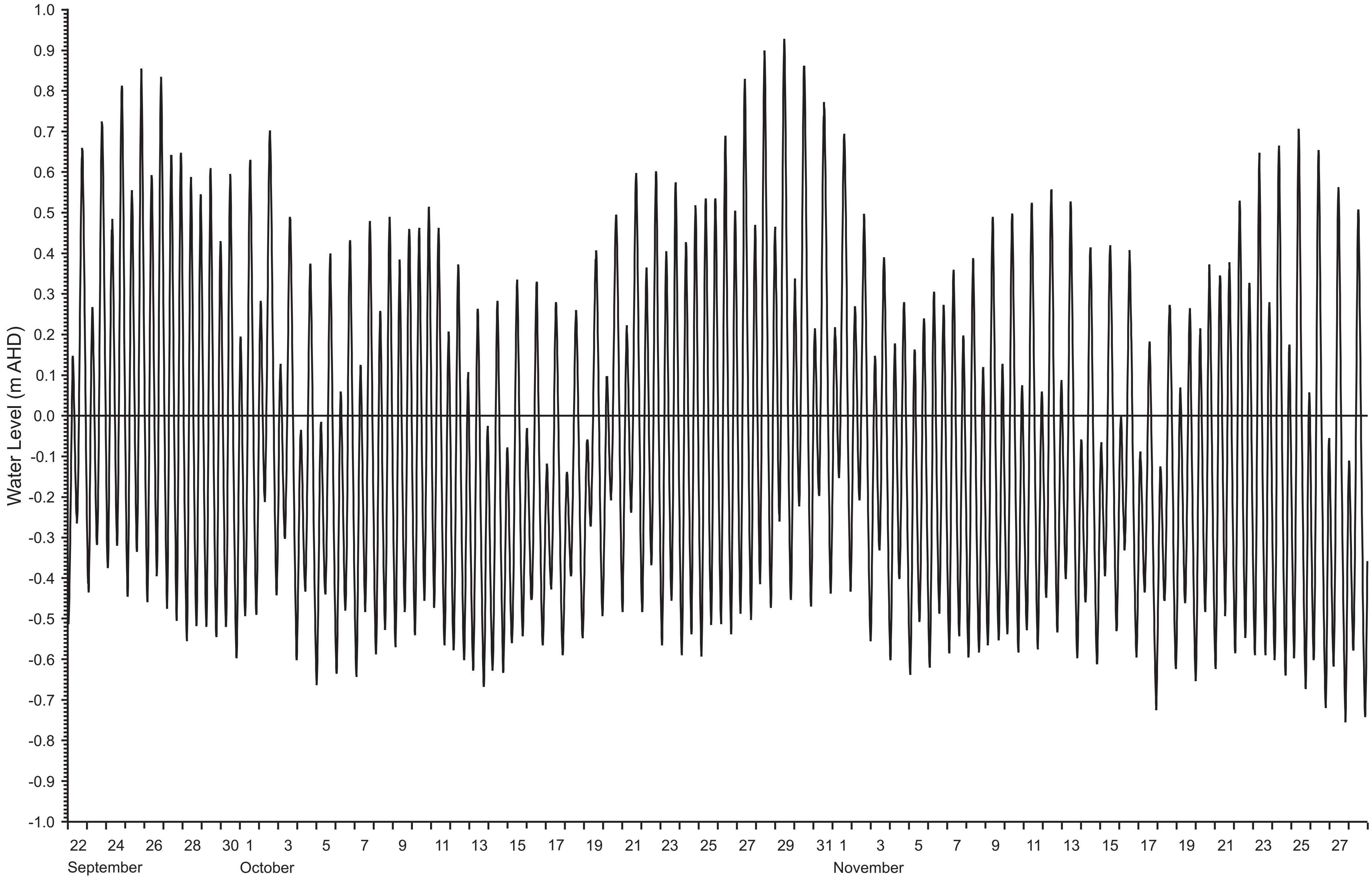

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Figure A10

DRAWING 1290-A10.CDR

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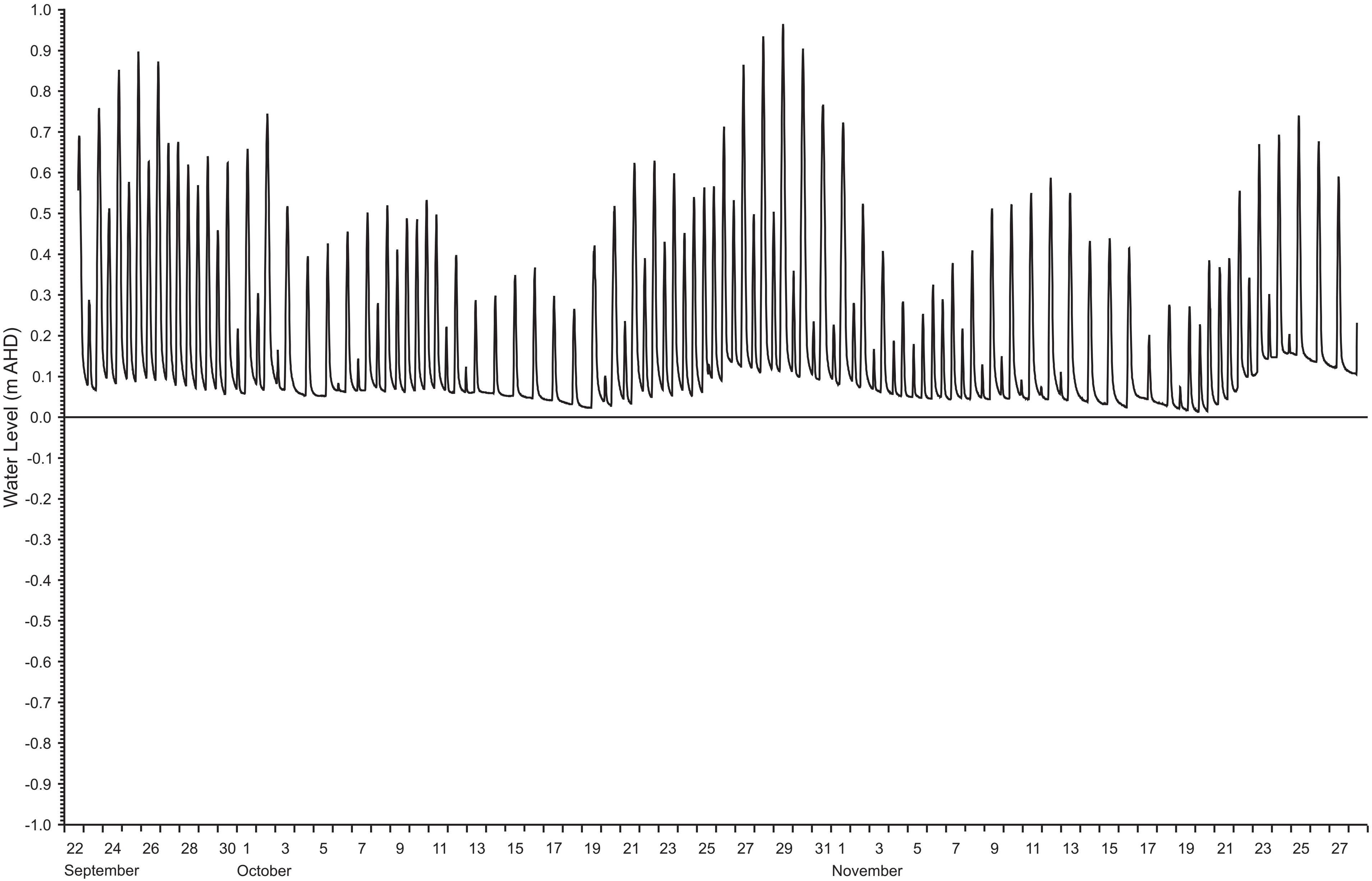
SITE 14 - UPPER PAMBULA RIVER
WATER LEVEL DATA
22 SEPTEMBER TO 28 NOVEMBER 2003



MHL Report 1290

Figure A11

DRAWING 1290-A11.CDR

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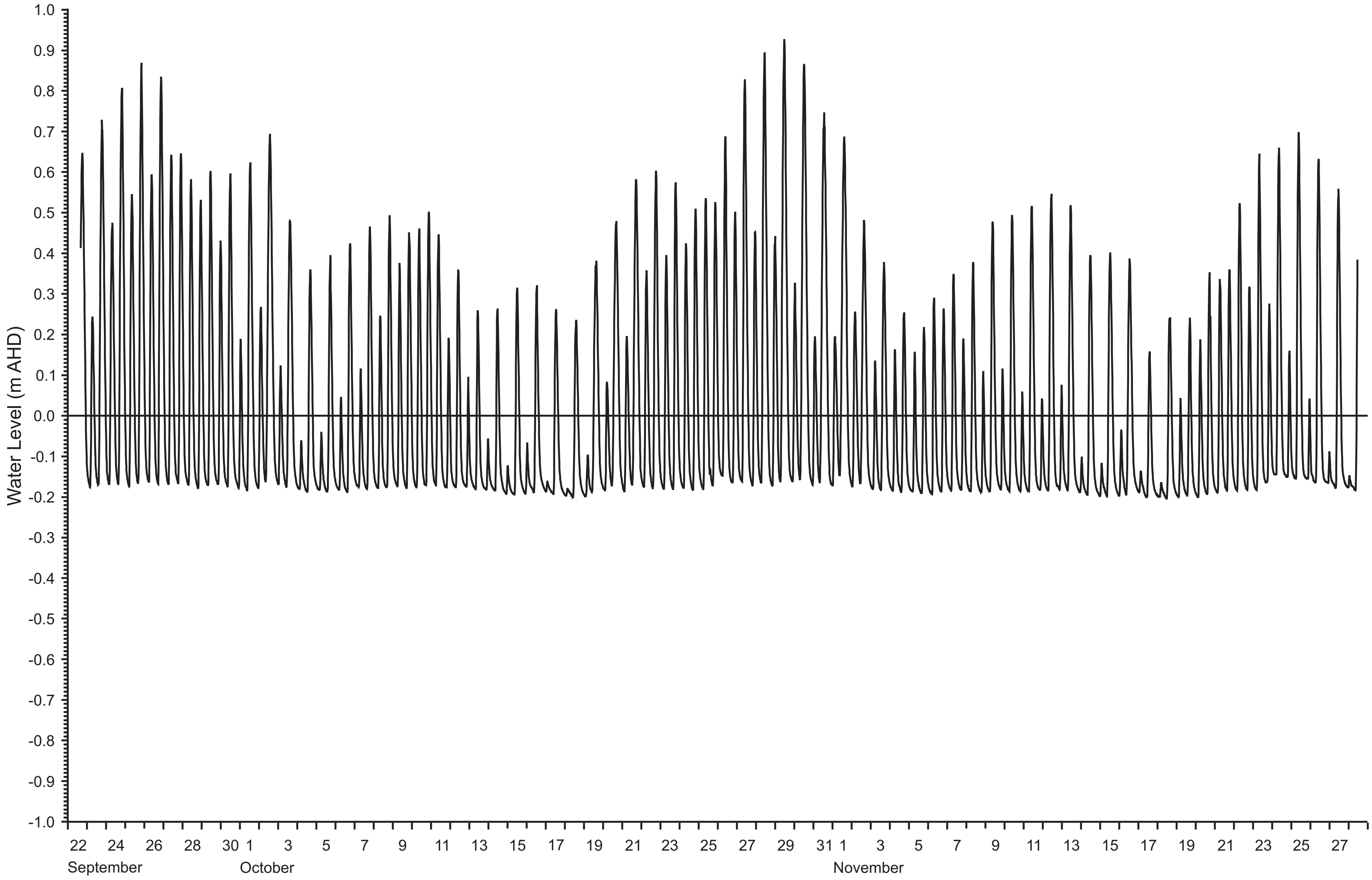
Commerce
MANLY HYDRAULICS LABORATORY

SITE 16 - YOWAKA RIVER
WATER LEVEL DATA
22 SEPTEMBER TO 28 NOVEMBER 2003



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Report 1290

Figure
A12

DRAWING 1290-A12.CDR

Appendix B

ADCP Transect Filenames

Sites 4, 10, 13 and 15

Table B1 ADCP Filenames - Site 4

Transect Number	Configuration Filename	Raw Data Filename (*R.000)	ASCII Filename (*T.000)
1	SITE4.WRC	MER_001	0401
2	SITE4.WRC	MER_002	0402
3	SITE4.WRC	MER_003	0403
4	SITE4.WRC	MER_004	0404
5	SITE4.WRC	MER_005	0405
6	SITE4.WRC	MER_006	0406
7	SITE4.WRC	MER_007	0407
8	SITE4.WRC	MER_008	0408
9	SITE4.WRC	MER_009	0409
10	SITE4.WRC	MER_010	0410
11	SITE4.WRC	MER_011	0411
12	SITE4.WRC	MER_012	0412
13	SITE4.WRC	MER_013	0413
14	SITE4.WRC	MER_014	0414
15	SITE4.WRC	MER_015	0415
16	SITE4.WRC	MER_016	0416
17	SITE4.WRC	MER_017	0417
18	SITE4.WRC	MER_018	0418
19	SITE4.WRC	MER_019	0419
20	SITE4.WRC	MER_020	0420
21	SITE4.WRC	MER_021	0421

Table B2 ADCP Filenames - Site 10

Transect Number	Configuration Filename	Raw Data Filename (*R.000)	ASCII Filename (*T.000)
1	SITE10.WRC	DATA001	1001
2	SITE10.WRC	DATA002	1002
3	SITE10.WRC	DATA003	1003
4	SITE10.WRC	DATA004	1004
5	SITE10.WRC	DATA005	1005
6	SITE10.WRC	DATA006	1006
7	SITE10.WRC	DATA007	1007
8	SITE10.WRC	DATA008	1008
9	SITE10.WRC	DATA009	1009
10	SITE10.WRC	DATA010	1010
11	SITE10.WRC	DATA011	1011
12	SITE10.WRC	DATA012	1012
13	SITE10.WRC	DATA013	1013
14	SITE10.WRC	DATA014	1014
15	SITE10.WRC	DATA015	1015
16	SITE10.WRC	DATA016	1016
17	SITE10.WRC	DATA017	1017
18	SITE10.WRC	DATA018	1018
19	SITE10.WRC	DATA019	1019
20	SITE10.WRC	DATA020	1020
21	SITE10.WRC	DATA021	1021
22	SITE10.WRC	DATA022	1022
23	SITE10.WRC	DATA023	1023
24	SITE10.WRC	DATA024	1024
25	SITE10.WRC	DATA025	1025
26	SITE10.WRC	DATA026	1026
27	SITE10.WRC	DATA027	1027
28	SITE10.WRC	DATA028	1028
29	SITE10.WRC	DATA029	1029
30	SITE10.WRC	DATA030	1030

Table B3 ADCP Filenames - Site 13

Transect Number	Configuration Filename	Raw Data Filename (*R.000)	ASCII Filename (*T.000)
1	SITE 13_15.WRC	DATA_005	1301
2	SITE 13_15.WRC	DATA_007	1302
3	MERIMBULA.CFG	MERI003	1303
4	MERIMBULA.CFG	MERI004	1304
5	MERIMBULA.CFG	MERI006	1305
6	MERIMBULA.CFG	MERI008	1306
7	MERIMBULA.CFG	MERI010	1307
8	MERIMBULA.CFG	MERI012	1308
9	MERIMBULA.CFG	MERI014	1309
10	MERIMBULA.CFG	MERI016	1310
11	MERIMBULA.CFG	MERI018	1311
12	MERIMBULA.CFG	MERI020	1312
13	MERIMBULA.CFG	MERI022	1313
14	MERIMBULA.CFG	MERI025	1314
15	MERIMBULA.CFG	MERI026	1315
16	MERIMBULA.CFG	MERI027	1316
17	MERIMBULA.CFG	MERI028	1317
18	MERIMBULA.CFG	MERI029	1318
19	MERIMBULA.CFG	MERI030	1319
20	MERIMBULA.CFG	MERI033	1320
21	MERIMBULA.CFG	MERI035	1321
22	MERIMBULA.CFG	MERI037	1322
23	MERIMBULA.CFG	MERI039	1323
24	MERIMBULA.CFG	MERI041	1324
25	MERIMBULA.CFG	MERI043	1325
26	MERIMBULA.CFG	MERI045	1326
27	MERIMBULA.CFG	MERI047	1327
28	MERIMBULA.CFG	MERI049	1328

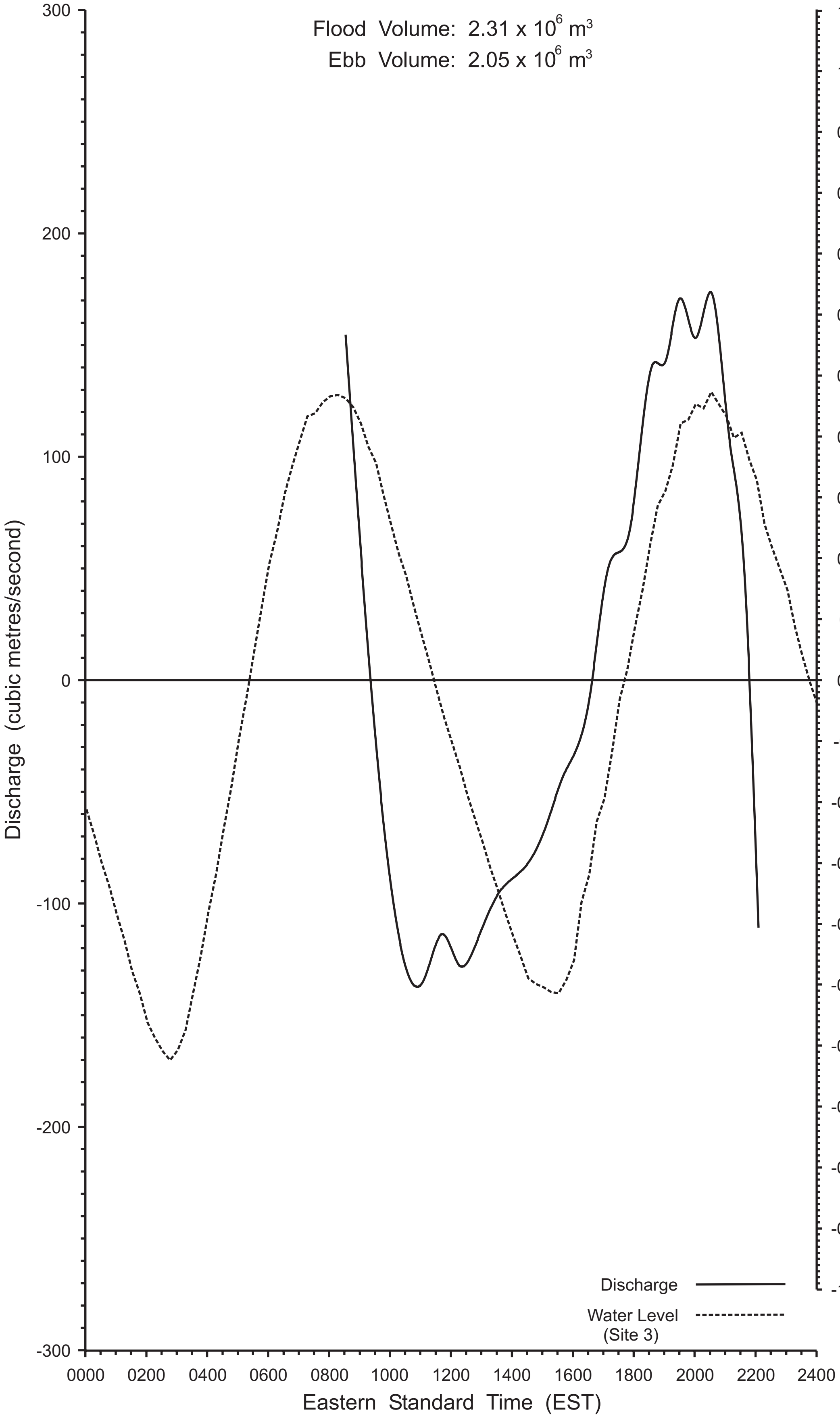
Table B4 ADCP Filenames - Site 15

Transect Number	Configuration Filename	Raw Data Filename (*R.000)	ASCII Filename (*T.000)
1	SITE 13_15.WRC	DATA_006	1501
2	MERIMBULA.CFG	MERI002	1502
3	MERIMBULA.CFG	MERI005	1503
4	MERIMBULA.CFG	MERI007	1504
5	MERIMBULA.CFG	MERI009	1505
6	MERIMBULA.CFG	MERI011	1506
7	MERIMBULA.CFG	MERI013	1507
8	MERIMBULA.CFG	MERI015	1508
9	MERIMBULA.CFG	MERI017	1509
10	MERIMBULA.CFG	MERI019	1510
11	MERIMBULA.CFG	MERI021	1511
12	MERIMBULA.CFG	MERI023	1512
13	MERIMBULA.CFG	MERI031	1513
14	MERIMBULA.CFG	MERI032	1514
15	MERIMBULA.CFG	MERI034	1515
16	MERIMBULA.CFG	MERI036	1516
17	MERIMBULA.CFG	MERI038	1517
18	MERIMBULA.CFG	MERI040	1518
19	MERIMBULA.CFG	MERI042	1519
20	MERIMBULA.CFG	MERI044	1520
21	MERIMBULA.CFG	MERI046	1521
22	MERIMBULA.CFG	MERI048	1522
23	MERIMBULA.CFG	MERI050	1523

Appendix C

Discharge Data

Sites 4, 10, 13 and 15



NSW Department of Commerce

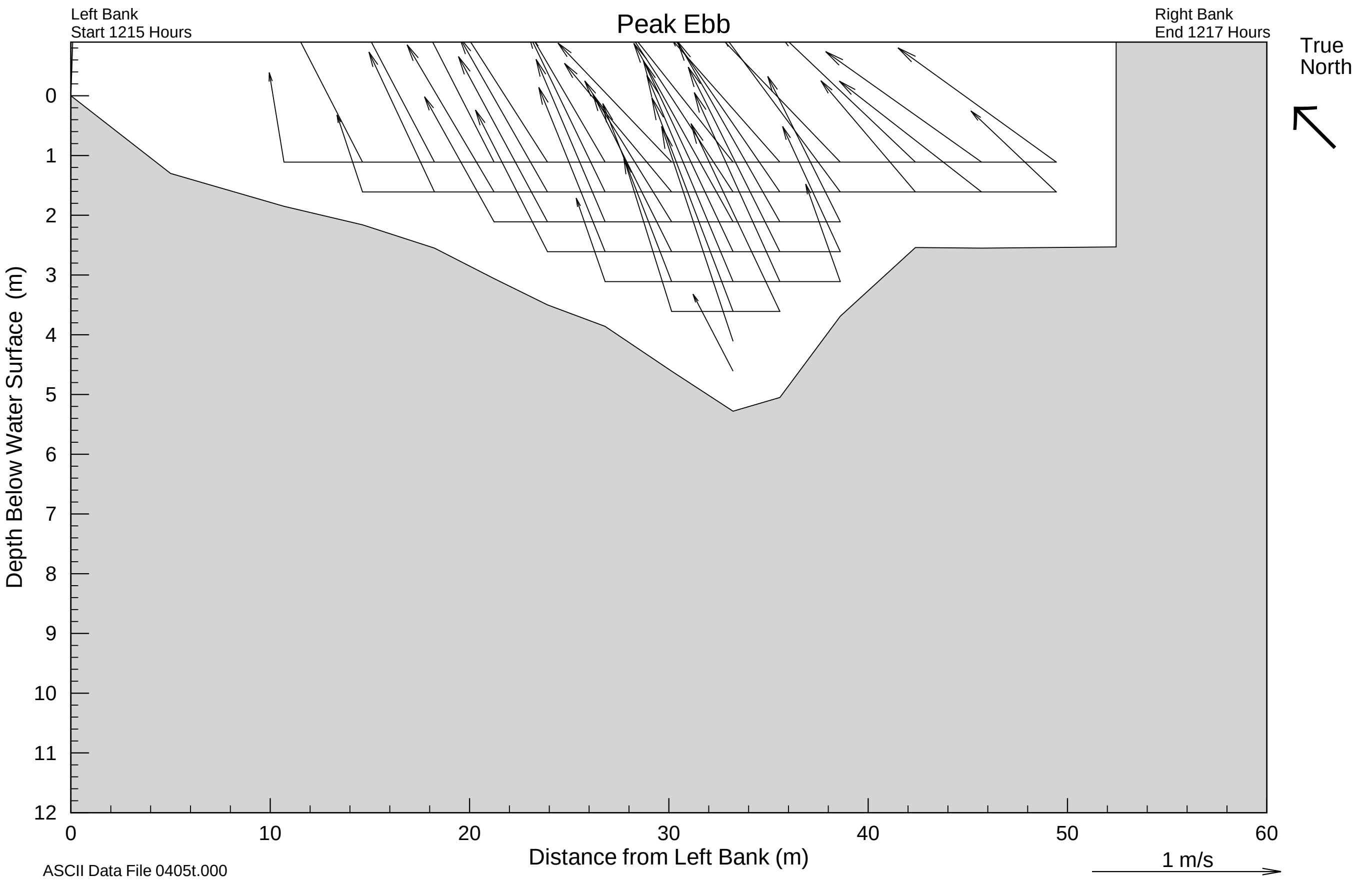
MANLY HYDRAULICS LABORATORY

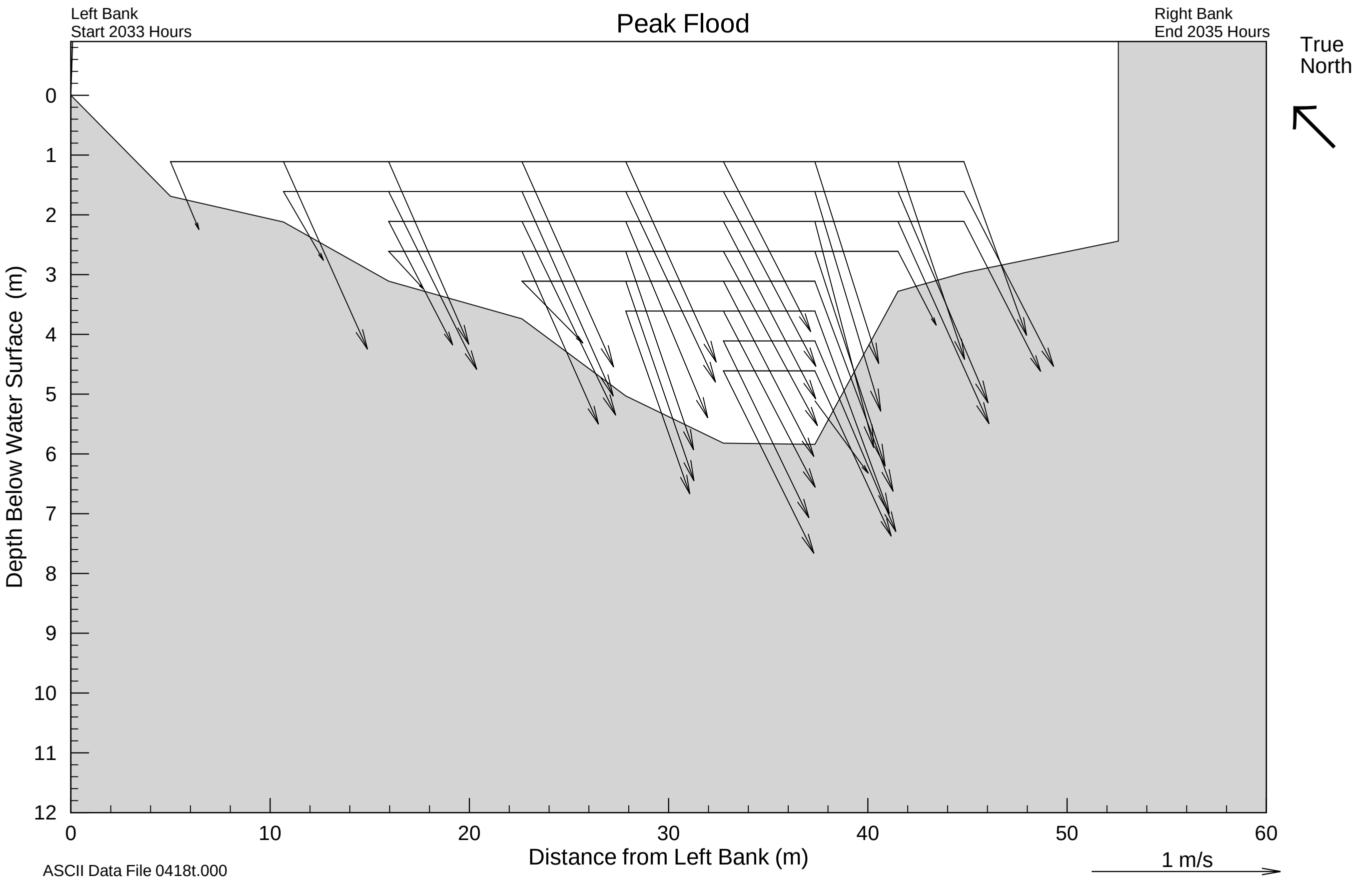
SITE 4 - MERIMBULA LAKE BRIDGE
DISCHARGE AND WATER LEVEL CURVES
25 OCTOBER 2003

MHL Report 1290

Figure C1

DRAWING 1290-C01.CDR





NSW Department of Commerce

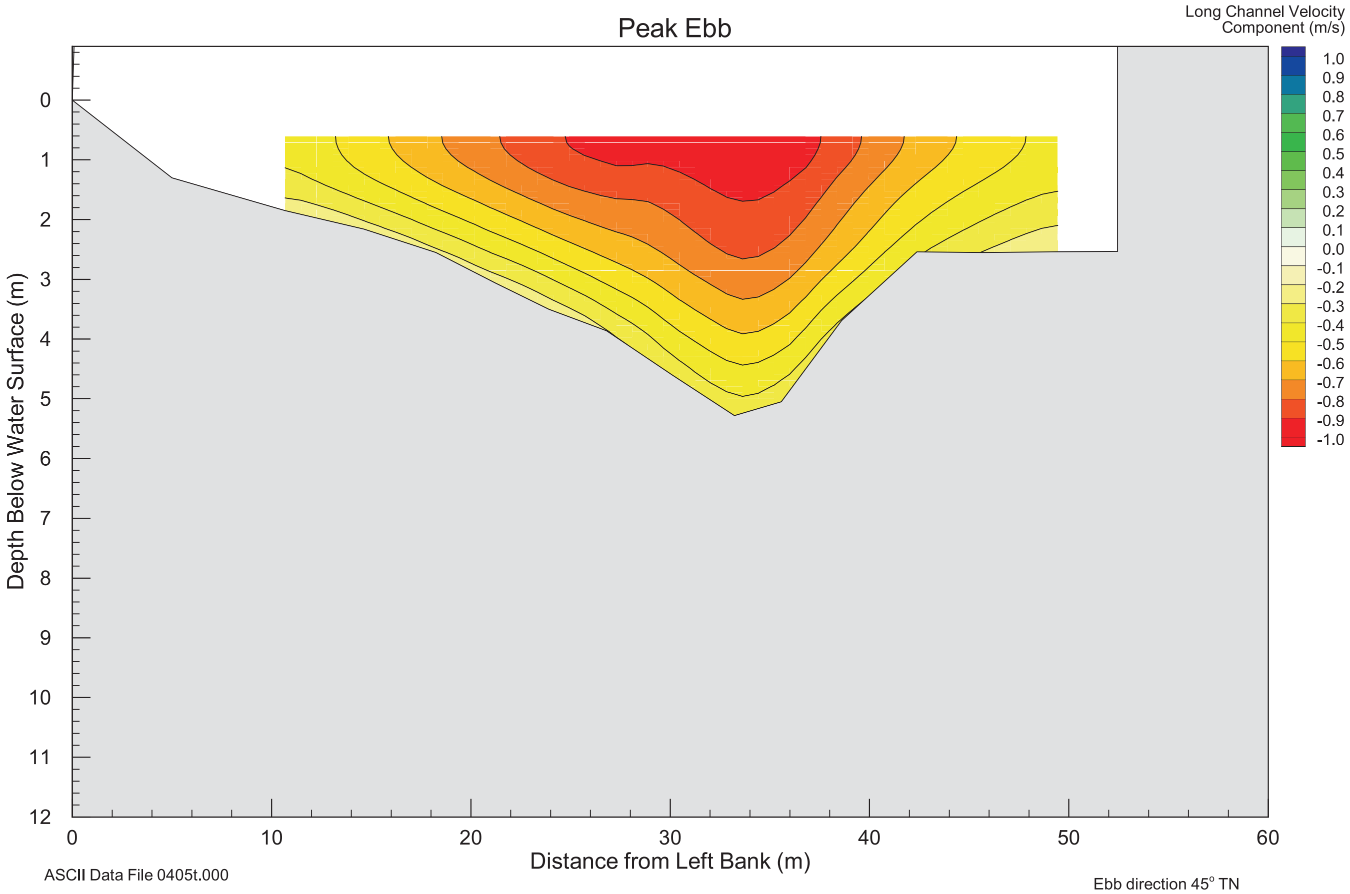
MANLY HYDRAULICS LABORATORY

SITE 4 - MERIMBULA LAKE BRIDGE
CURRENT SPEED DISTRIBUTION STICK PLOTS
PEAK DISCHARGE - 25 OCTOBER 2003

MHL Report 1290

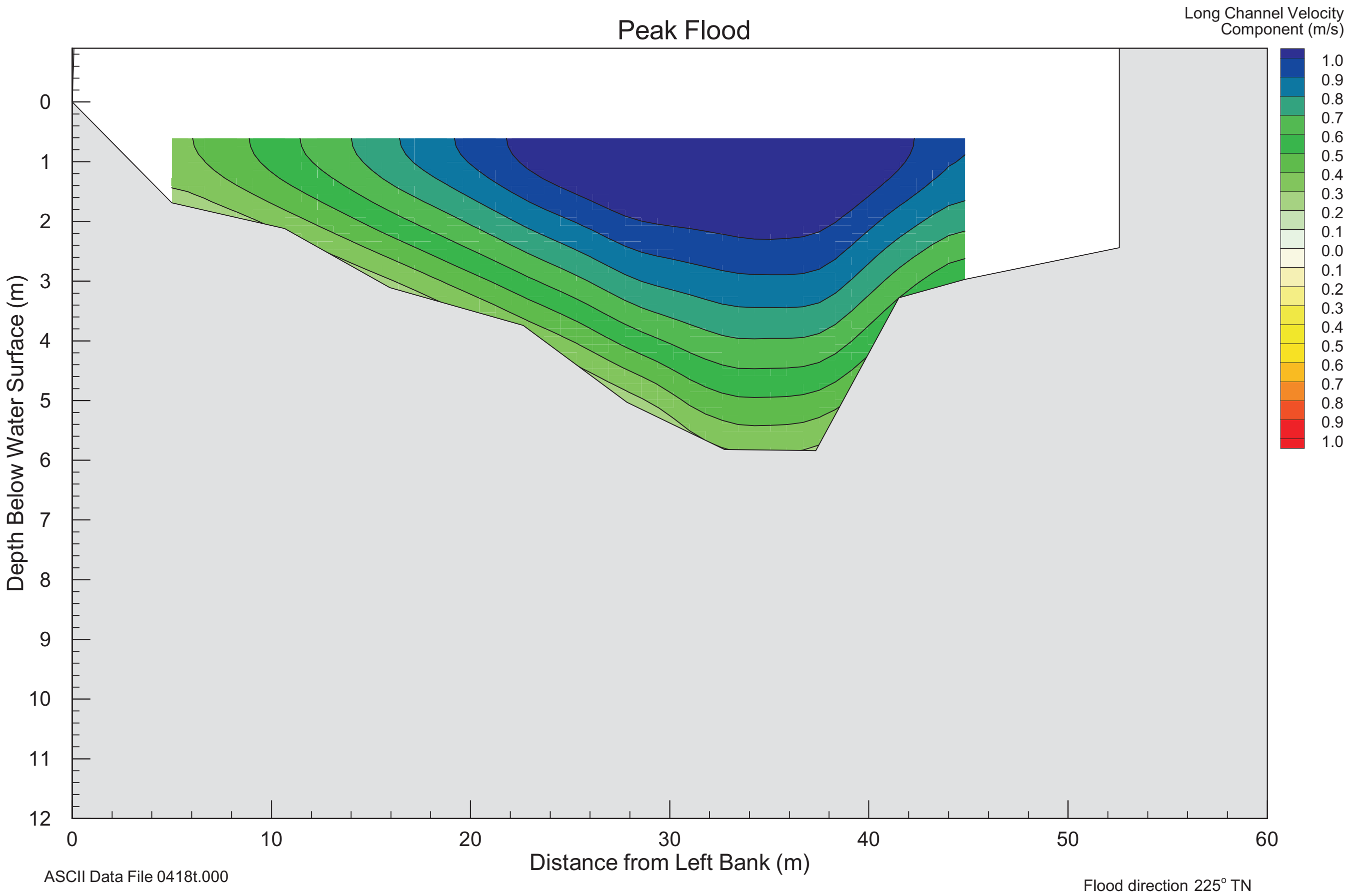
Figure C2

DRAWING 1290C002.BPS



ASCII Data File 0405t.000

Ebb direction 45° TN



ASCII Data File 0418t.000

Flood direction 225° TN

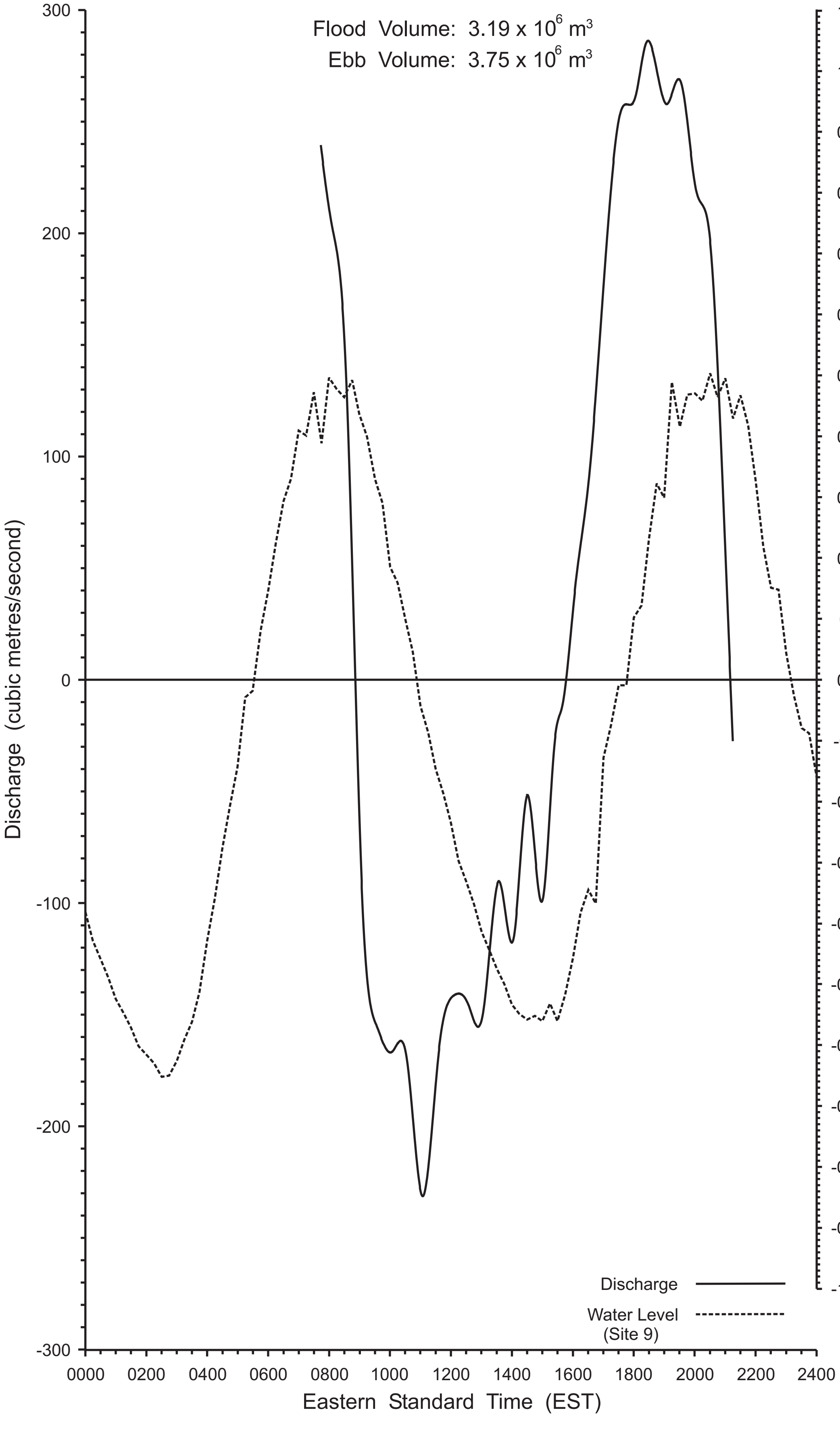
NSW Department of Commerce
MANLY HYDRAULICS LABORATORY

SITE 4 - MERIMBULA LAKE BRIDGE
CONTOURS OF LONG CHANNEL VELOCITY
PEAK DISCHARGE - 25 OCTOBER 2003

MHL Report 1290

Figure C3

DRAWING 1290C0003.BPS



NSW Department of Commerce

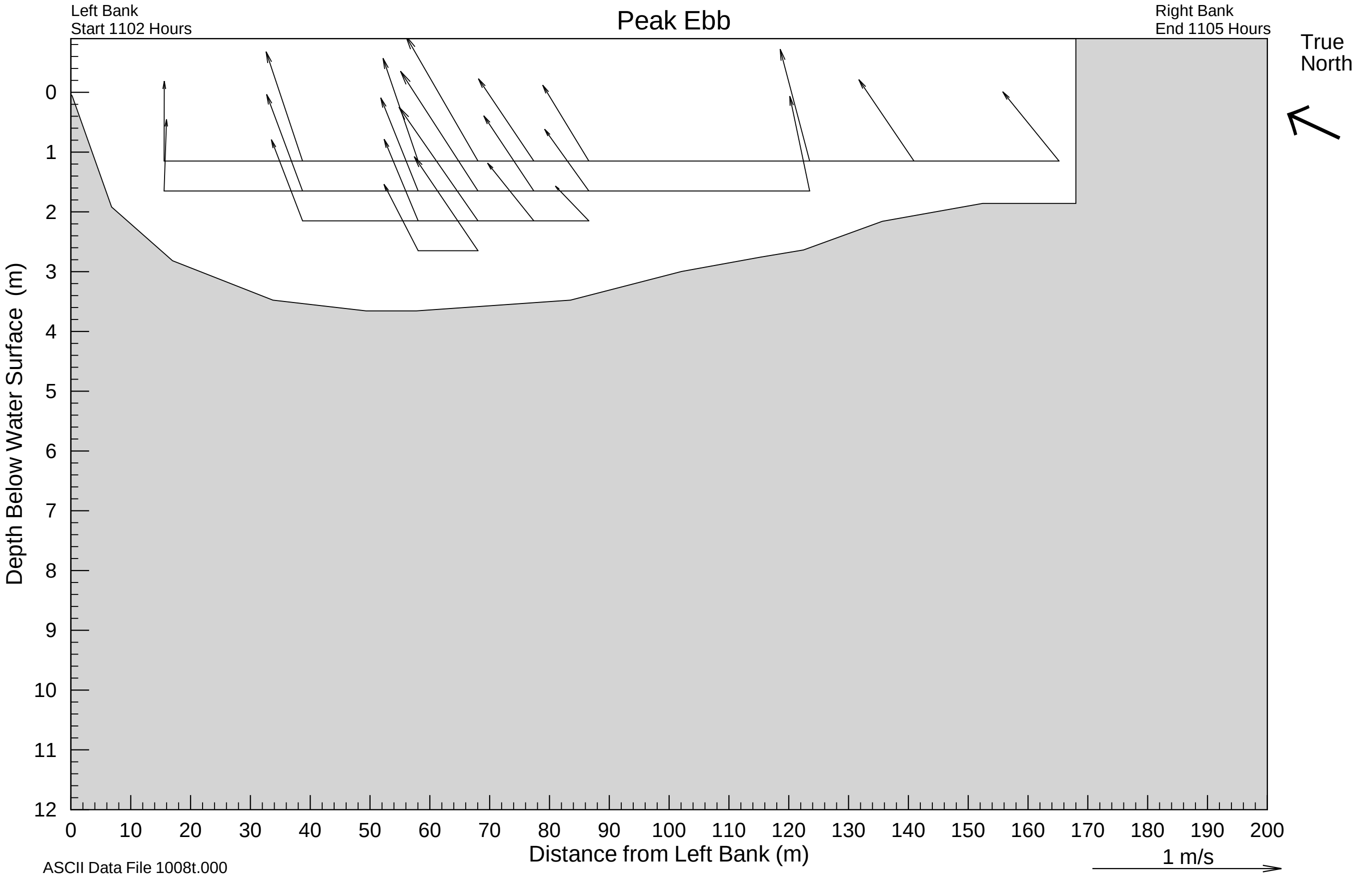
MANLY HYDRAULICS LABORATORY

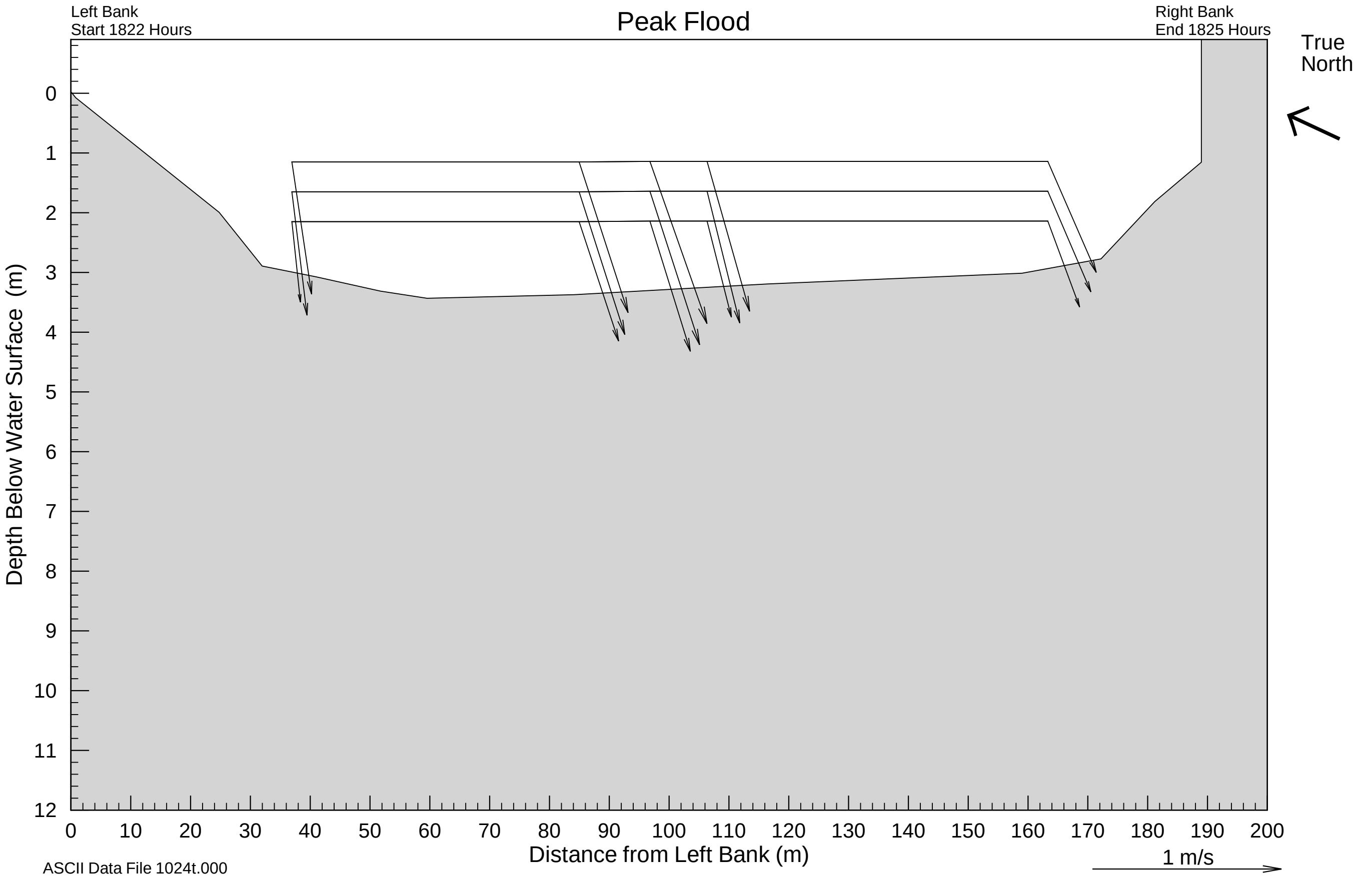
SITE 10 - PAMBULA RIVER DOWNSTREAM
DISCHARGE AND WATER LEVEL CURVES
25 OCTOBER 2003

MHL Report 1290

Figure C4

DRAWING 1290-C04.CDR





NSW Department of Commerce

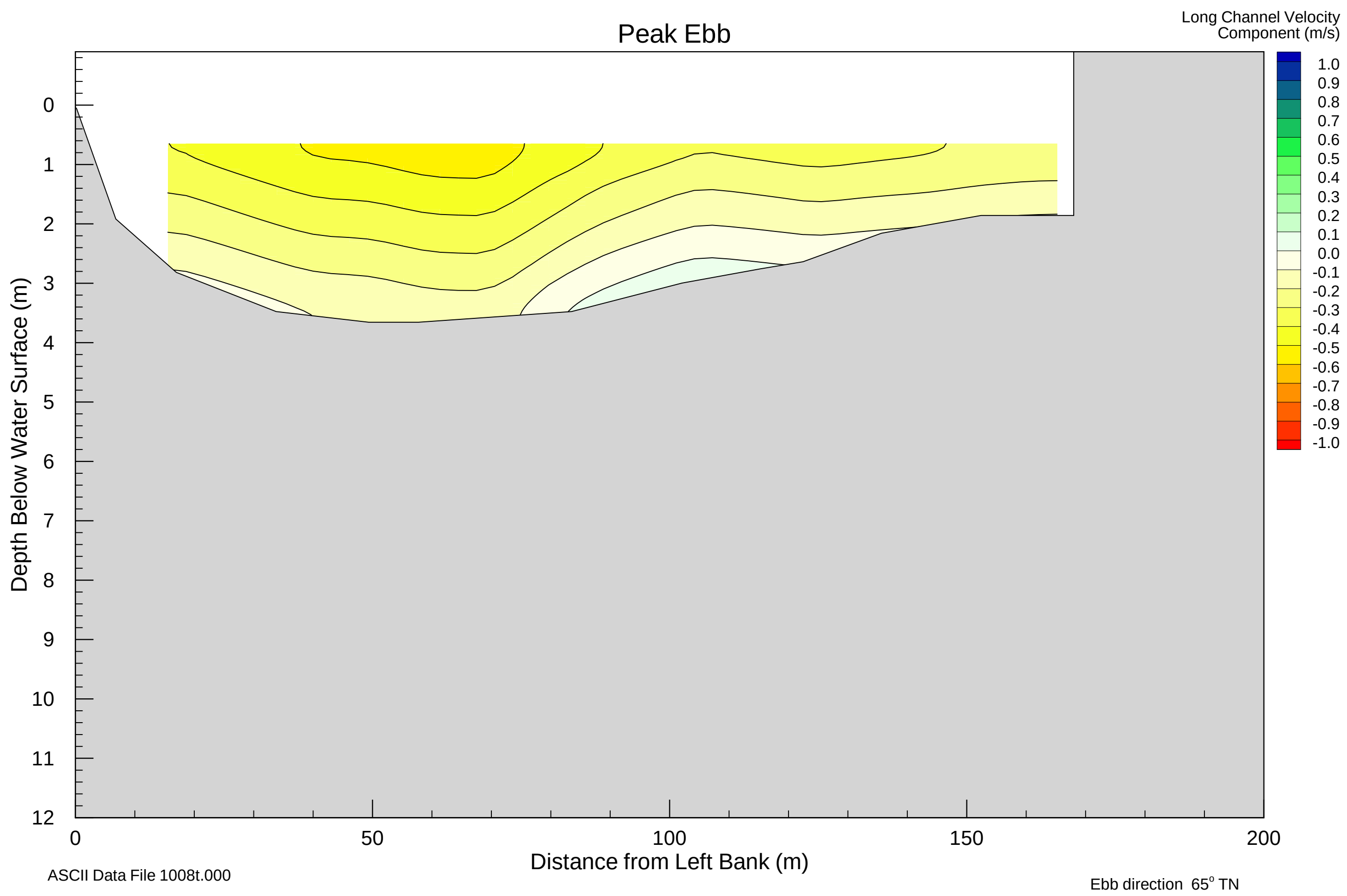
MANLY HYDRAULICS LABORATORY

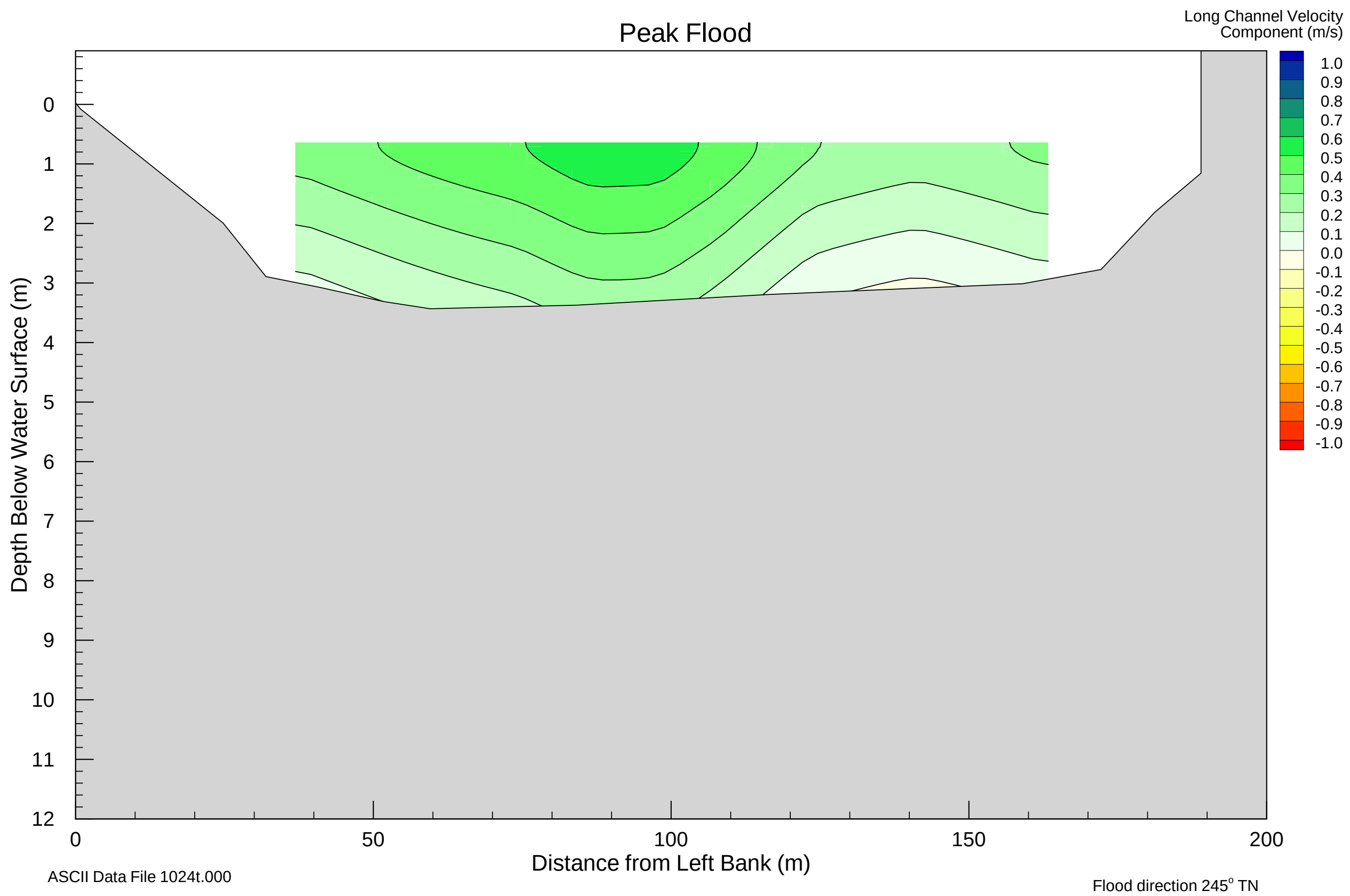
SITE 10 - PAMBULA RIVER DOWNSTREAM
CURRENT SPEED DISTRIBUTION STICK PLOTS
PEAK DISCHARGE - 25 OCTOBER 2003

MHL Report 1290

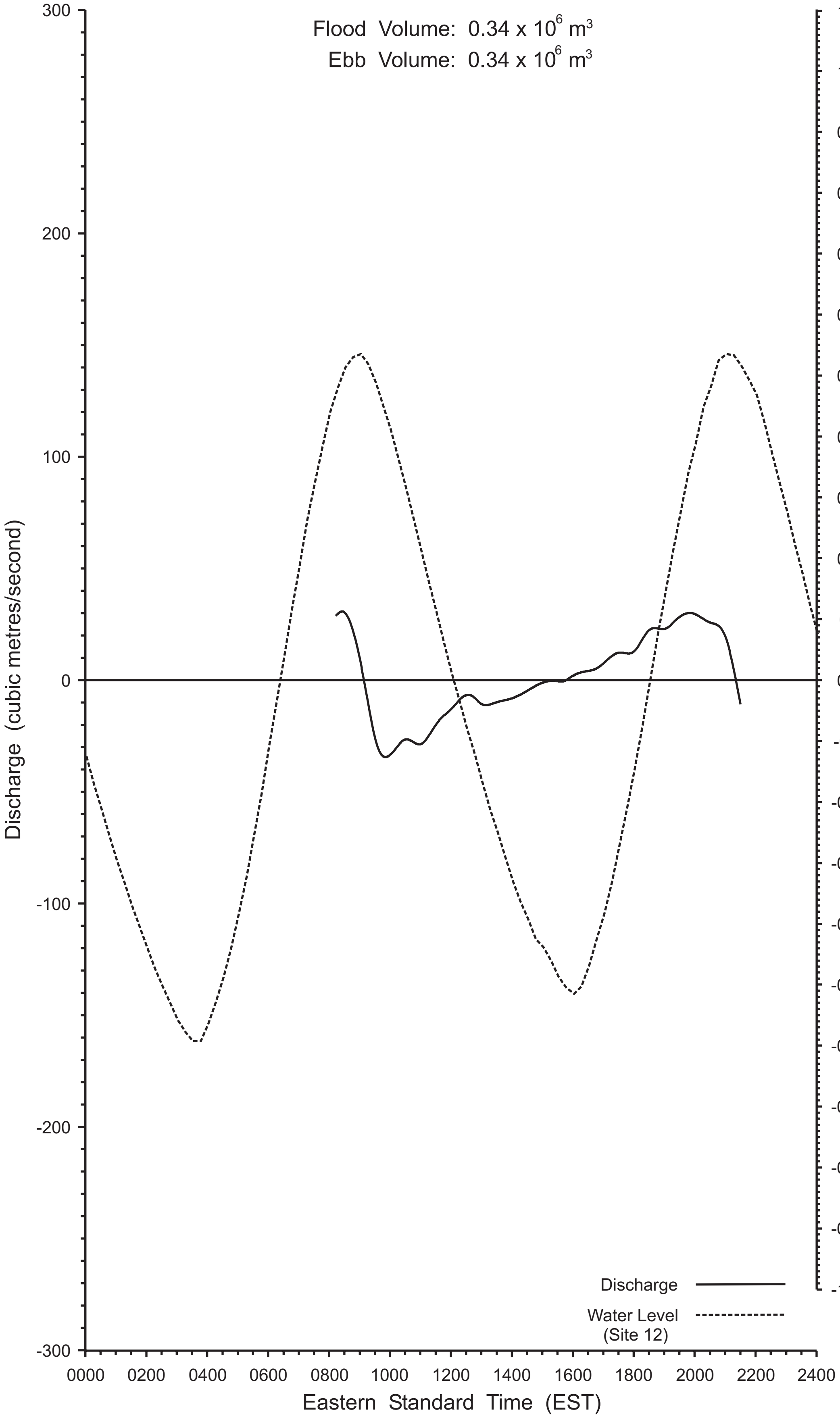
Figure C5

DRAWING 1290C005.BPS





NSW Department of Commerce MANLY HYDRAULICS LABORATORY	SITE 10 - PAMBULA RIVER DOWNSTREAM CONTOURS OF LONG CHANNEL VELOCITY PEAK DISCHARGE - 25 OCTOBER 2003	MHL Report 1290 Figure C6 DRAWING 1290C006.BPS



NSW Department of Commerce

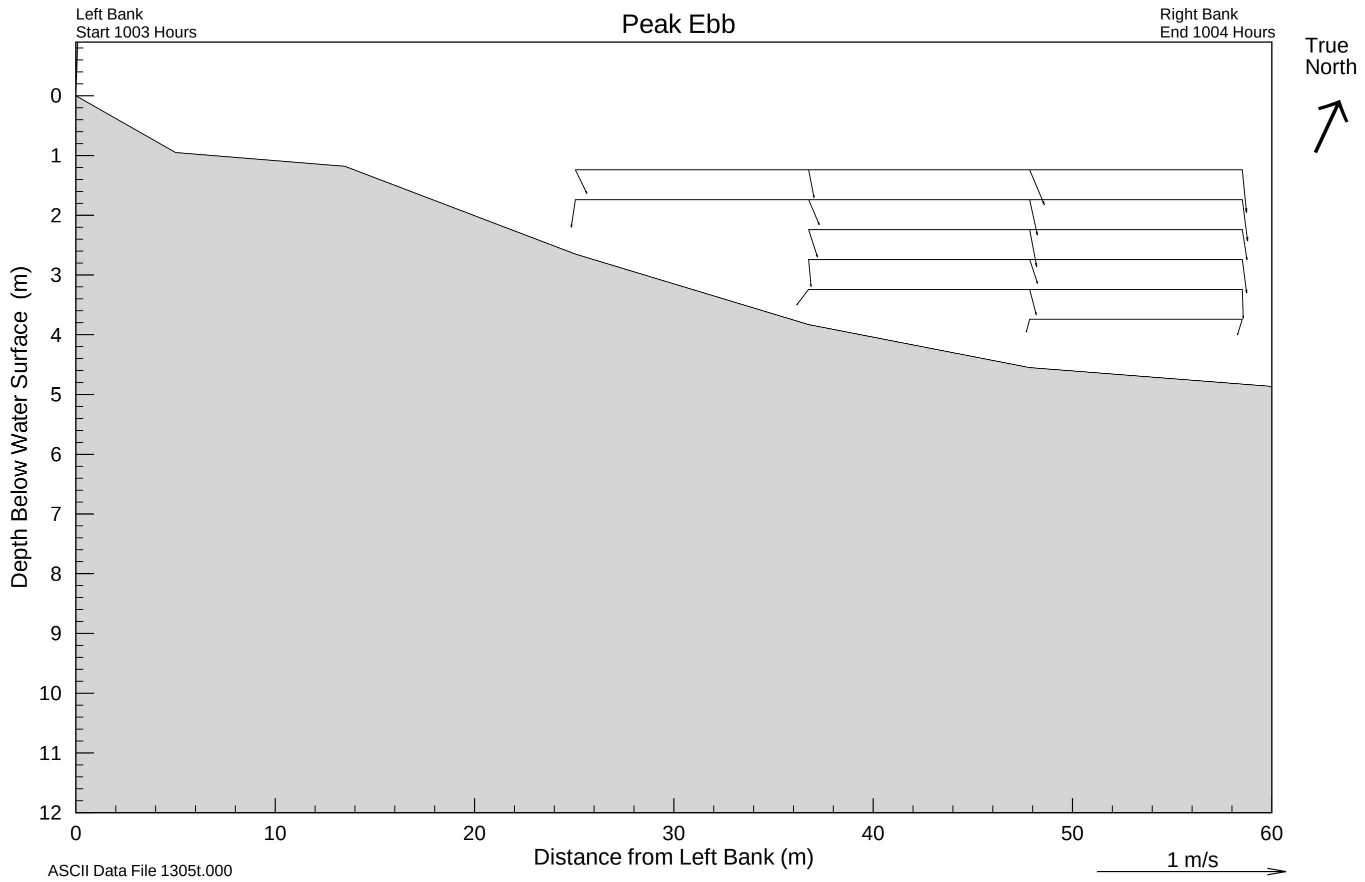
MANLY HYDRAULICS LABORATORY

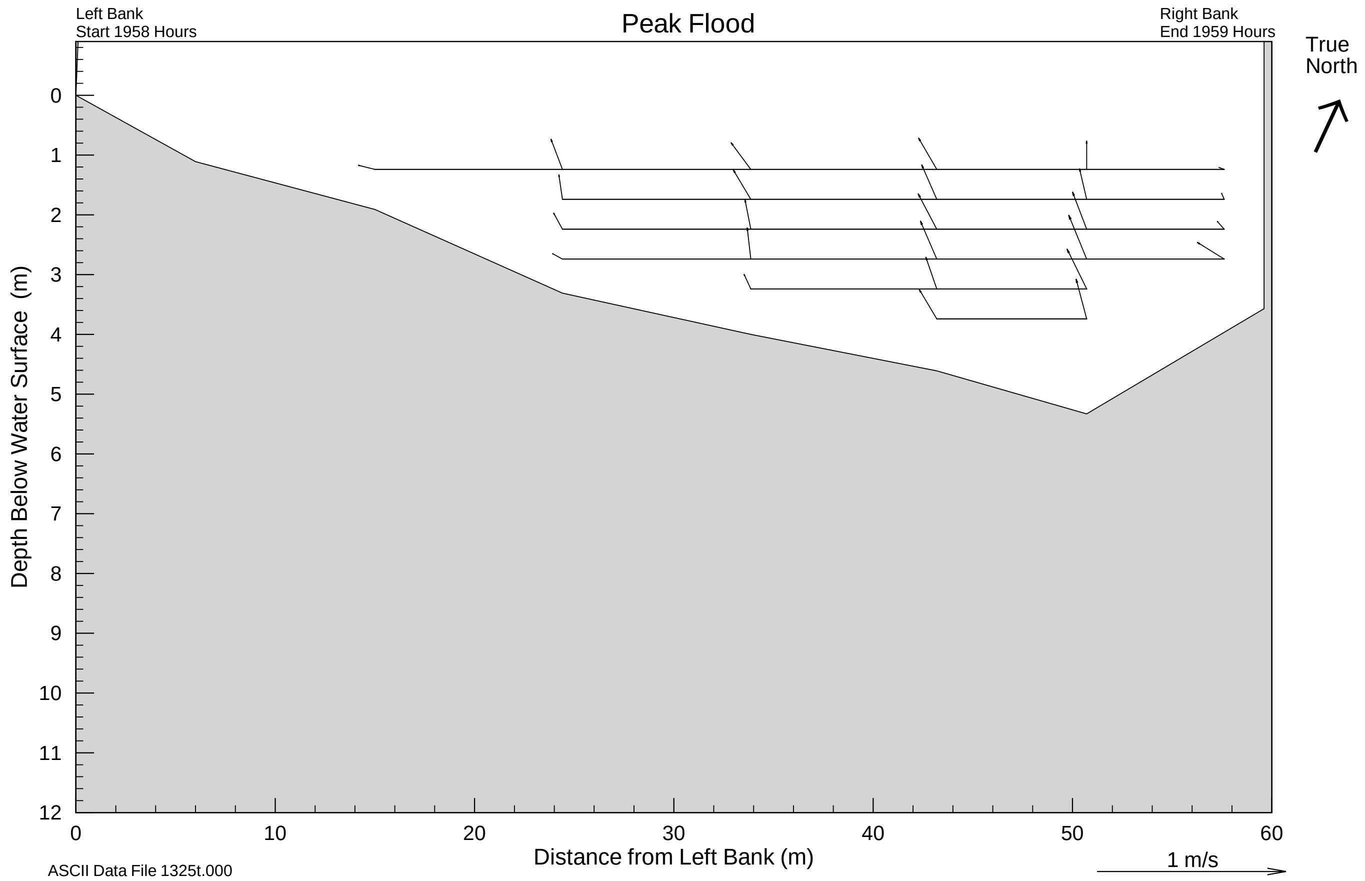
SITE 13 - PAMBULA RIVER UPSTREAM
DISCHARGE AND WATER LEVEL CURVES
25 OCTOBER 2003

MHL Report 1290

Figure C7

DRAWING 1290-C07.CDR





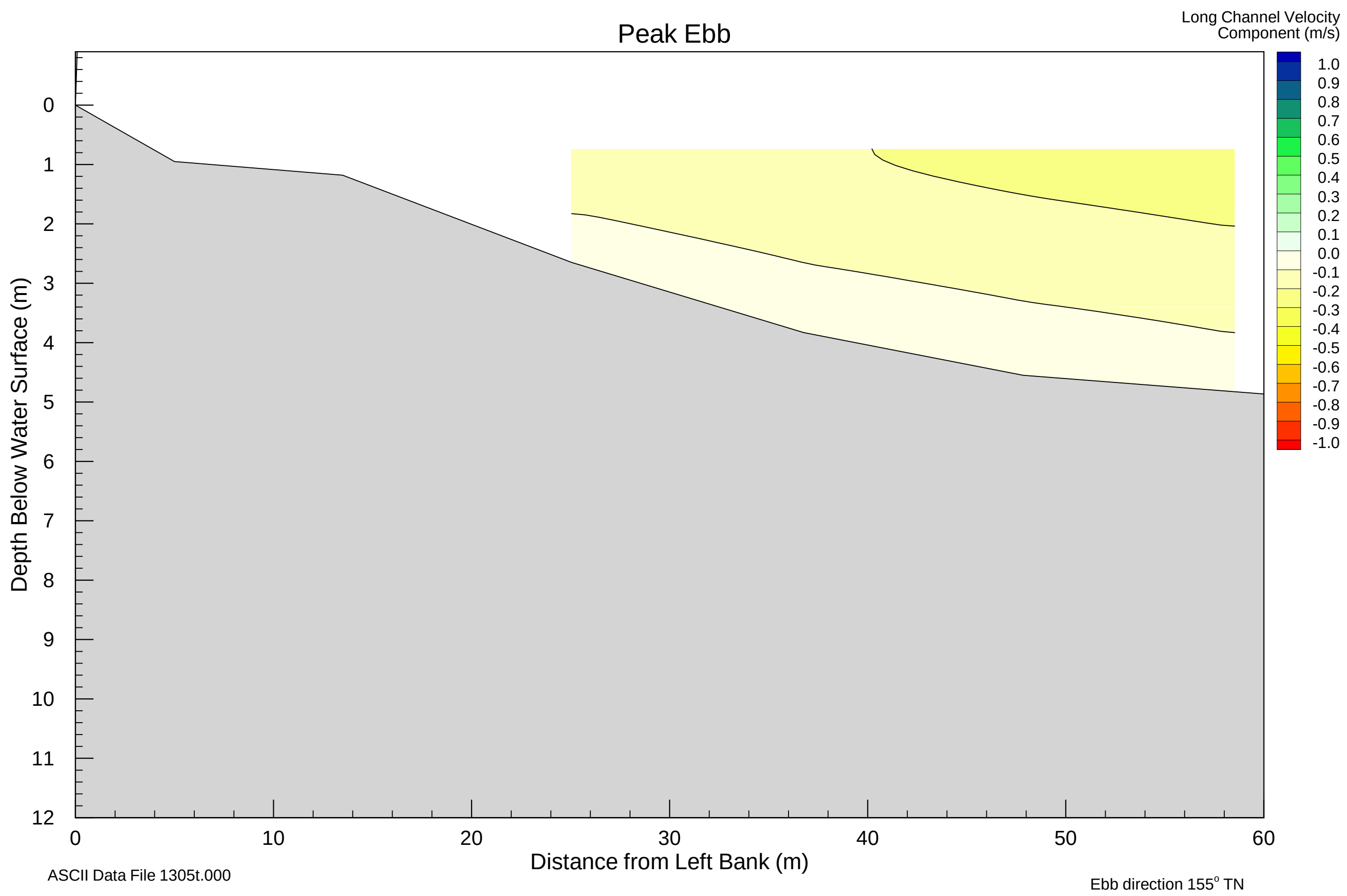
NSW Department of Commerce
MANLY HYDRAULICS LABORATORY

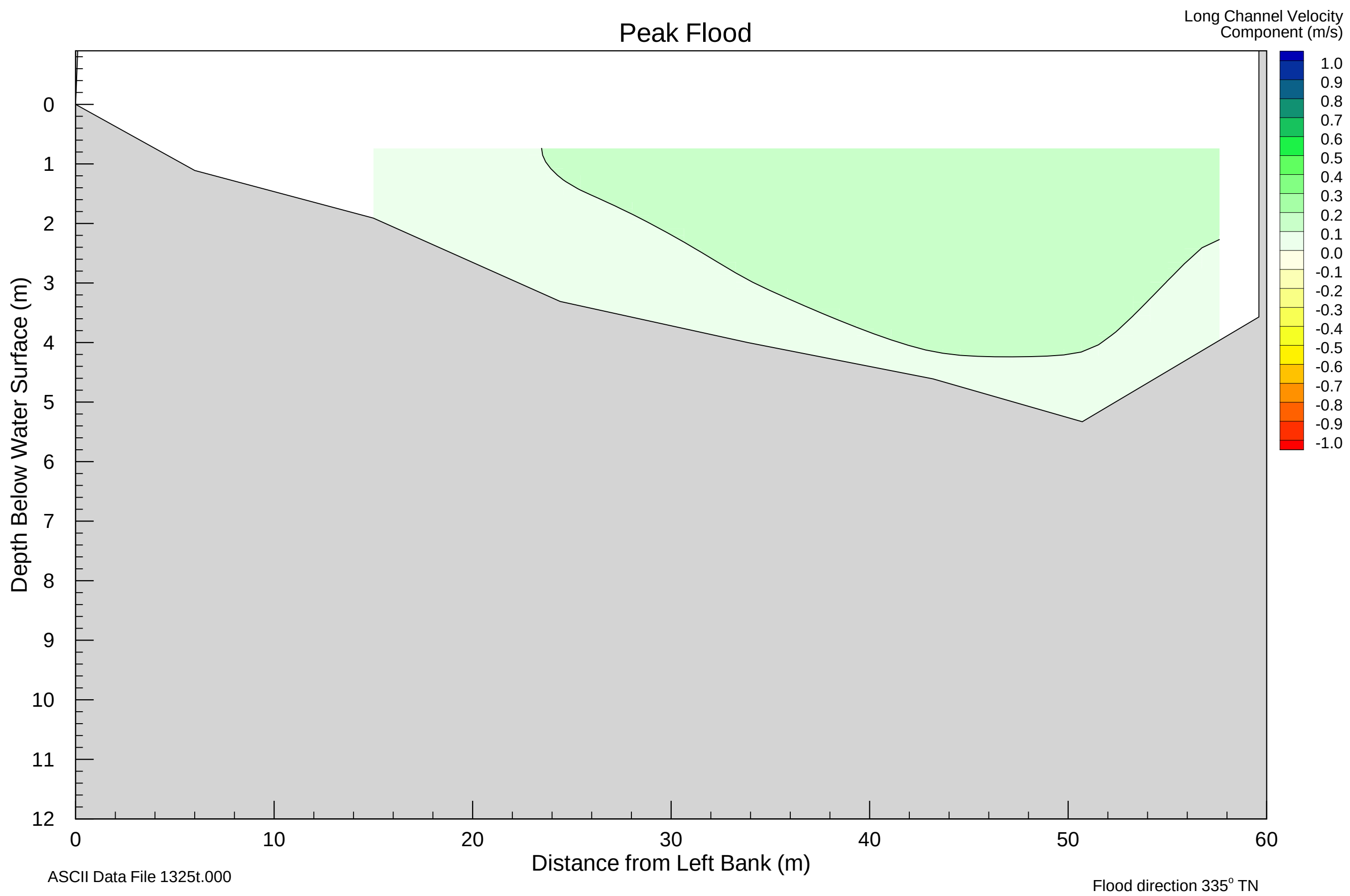
SITE 13 - PAMBULA RIVER UPSTREAM
CURRENT SPEED DISTRIBUTION STICK PLOTS
PEAK DISCHARGE - 25 OCTOBER 2003

MHL Report 1290

Figure C8

DRAWING 1290C008.BPS

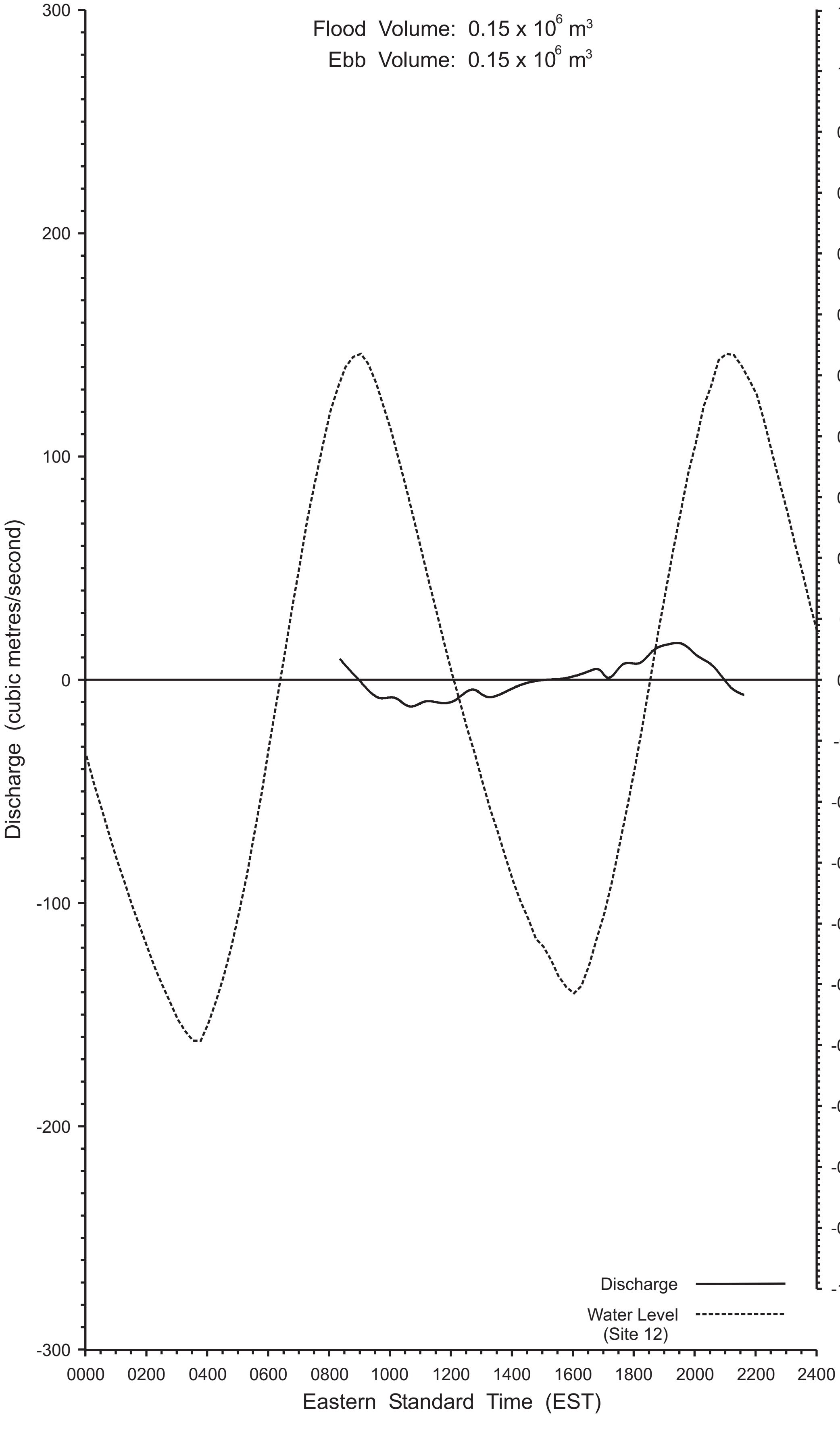




NSW Department of Commerce
MANLY HYDRAULICS LABORATORY

SITE 13 - PAMBULA RIVER UPSTREAM
CONTOURS OF LONG CHANNEL VELOCITY
PEAK DISCHARGE - 25 OCTOBER 2003

MHL Report 1290
Figure C9
DRAWING 1290C009.BPS



NSW Department of Commerce

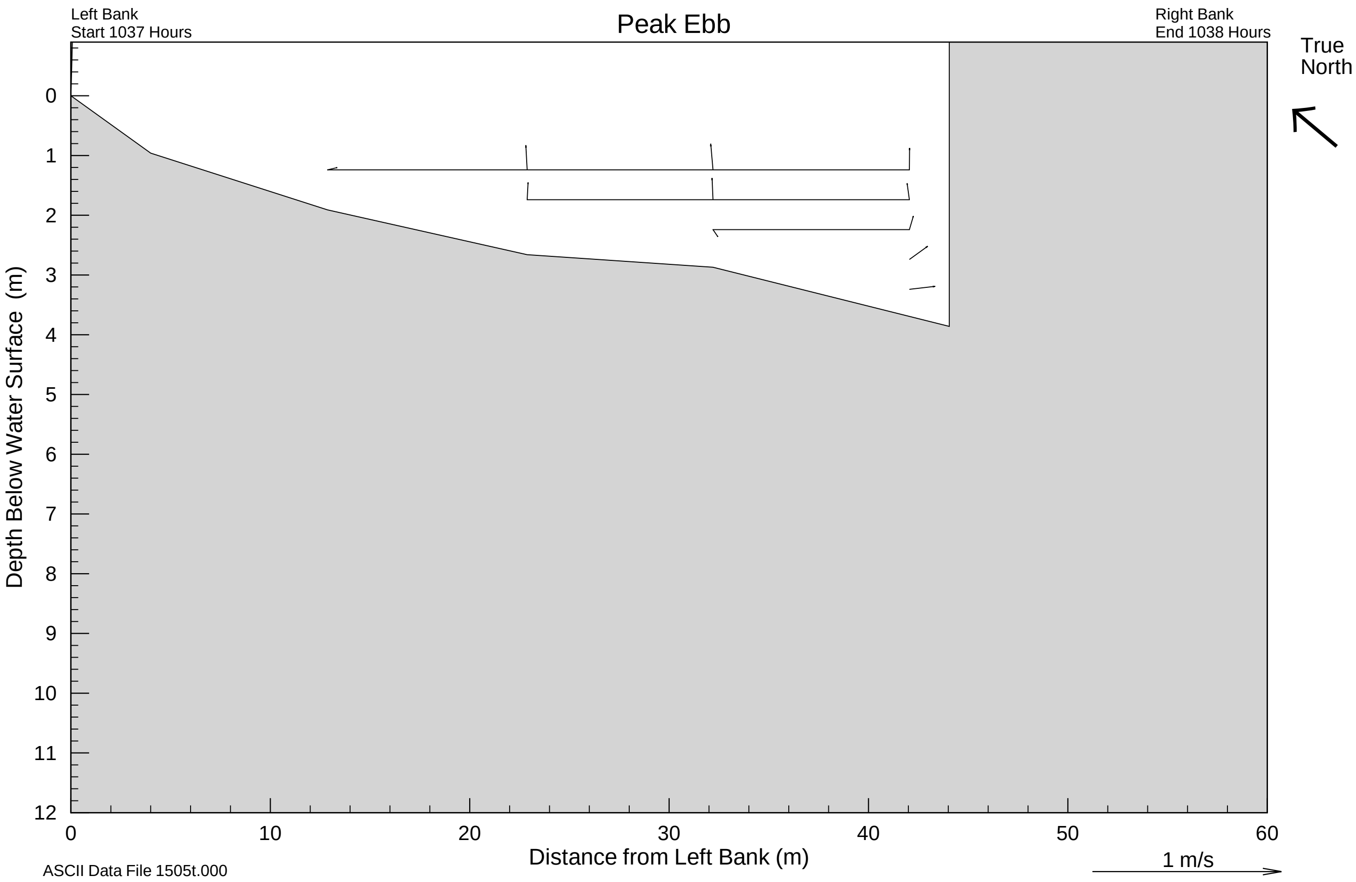
MANLY HYDRAULICS LABORATORY

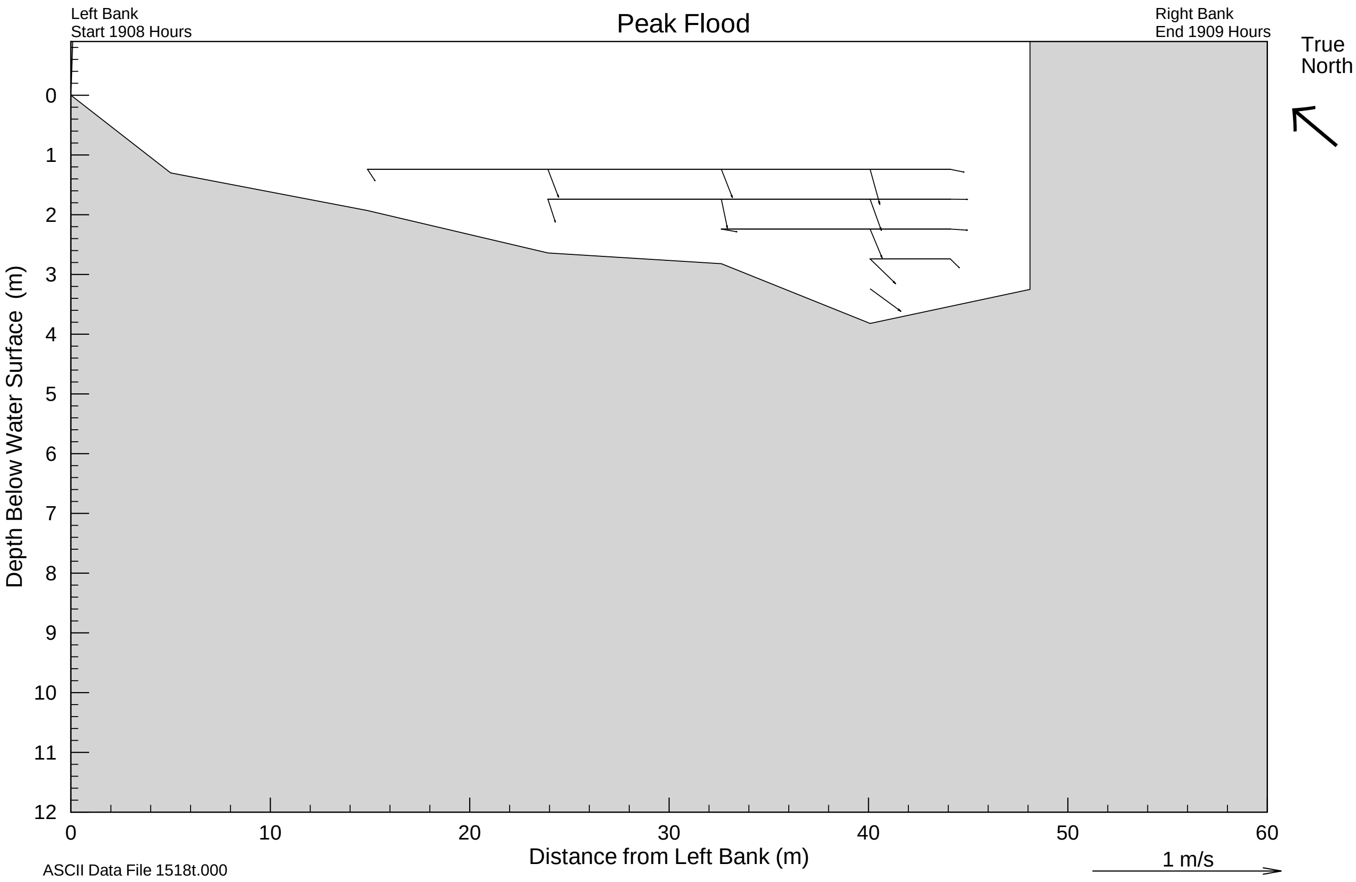
SITE 15 - YOWAKA RIVER
DISCHARGE AND WATER LEVEL CURVES
25 OCTOBER 2003

MHL Report 1290

Figure C10

DRAWING 1290-C10.CDR





NSW Department of Commerce

MANLY HYDRAULICS LABORATORY

SITE 15 - YOWAKA RIVER

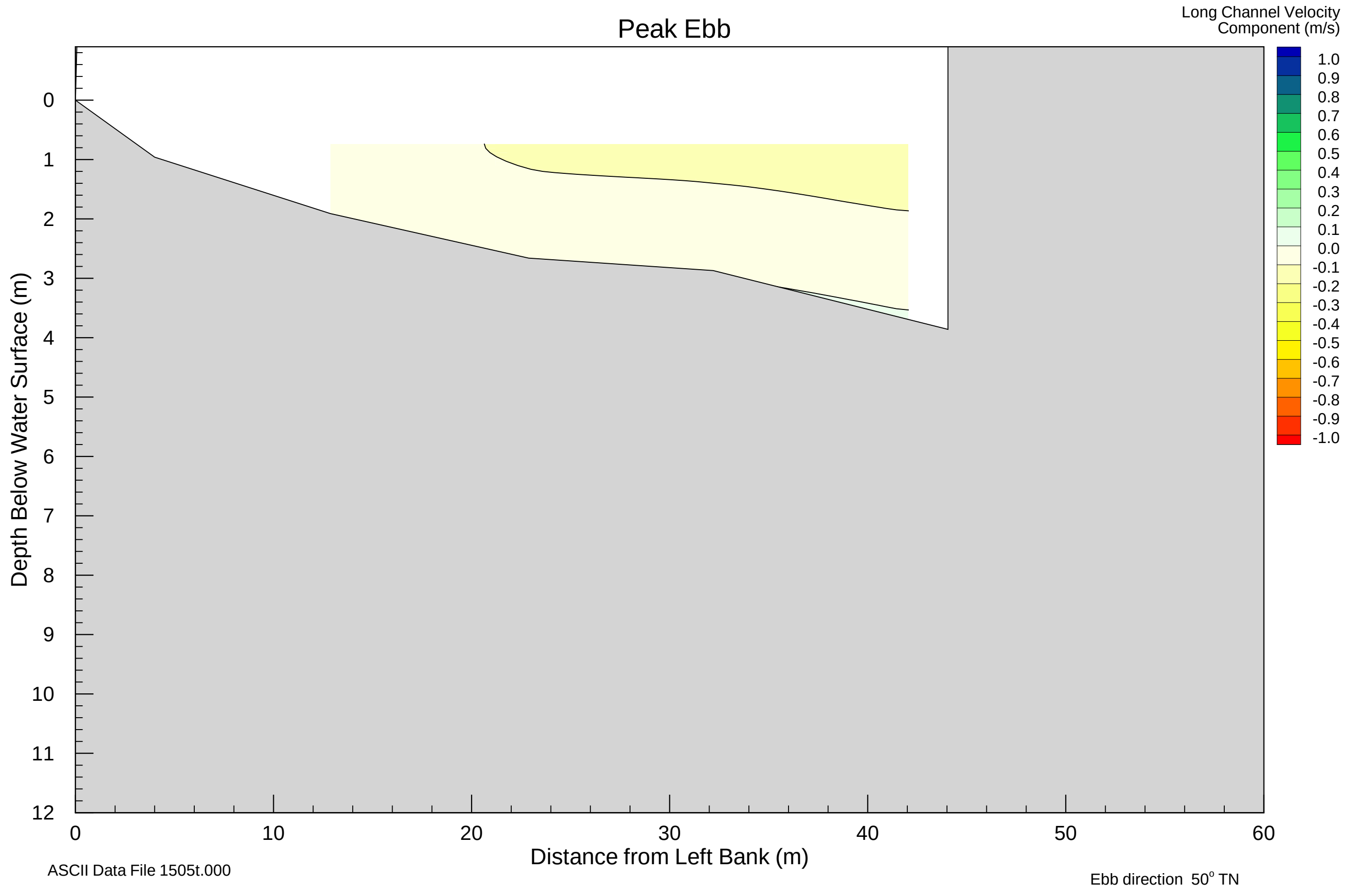
CURRENT SPEED DISTRIBUTION STICK PLOTS

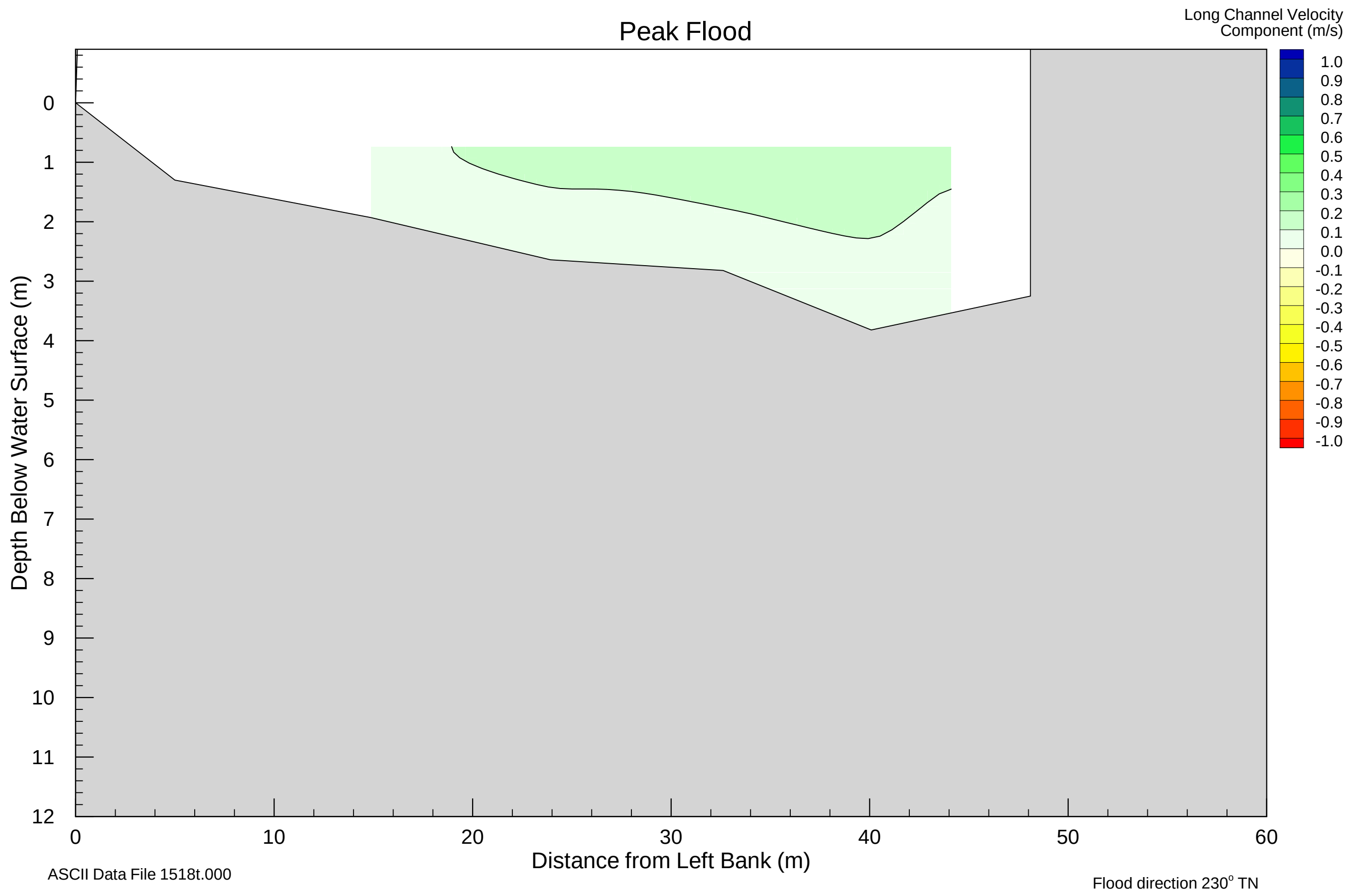
PEAK DISCHARGE - 25 OCTOBER 2003

MHL Report 1290

Figure C11

DRAWING 1290C011.BPS

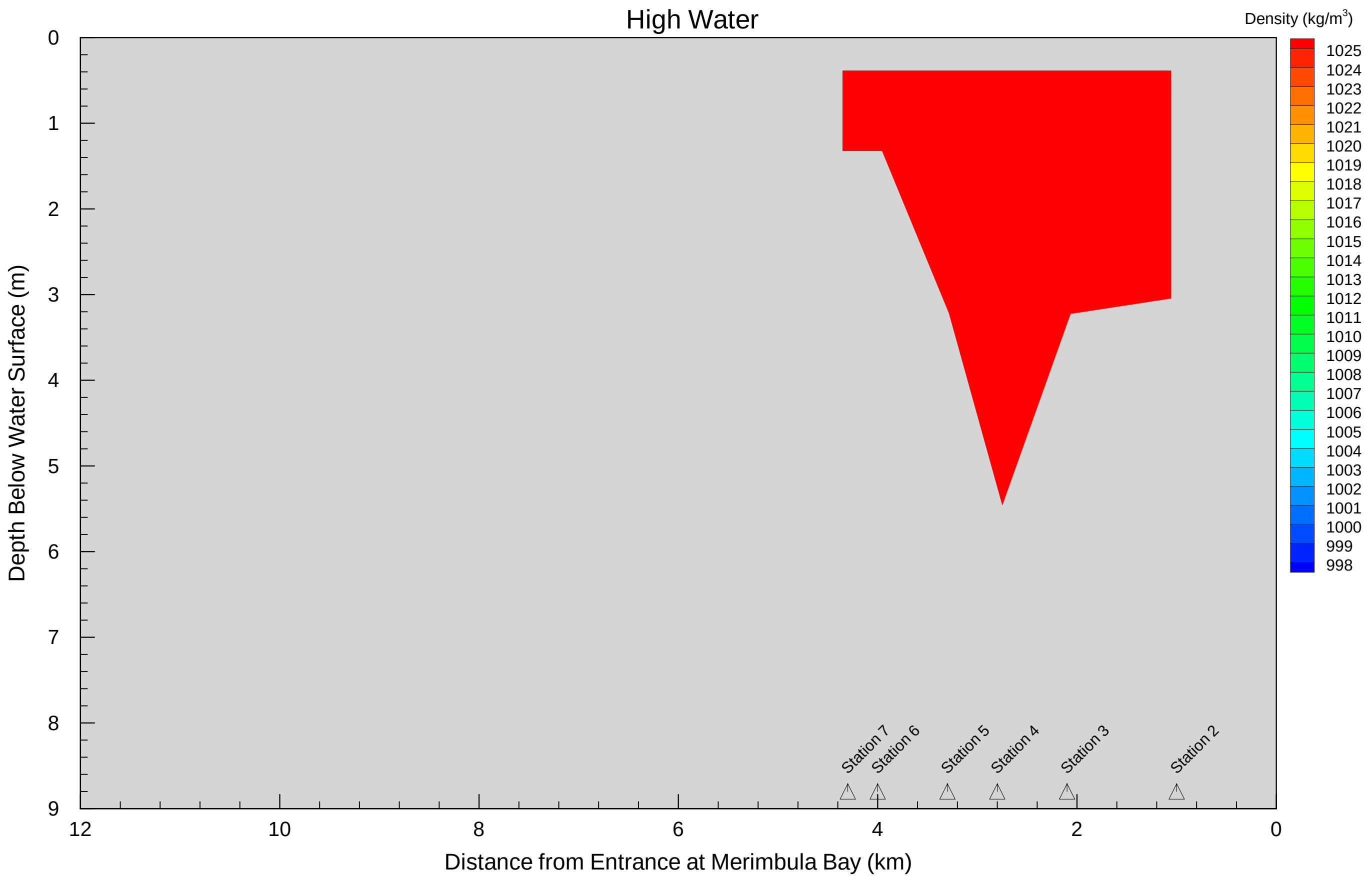


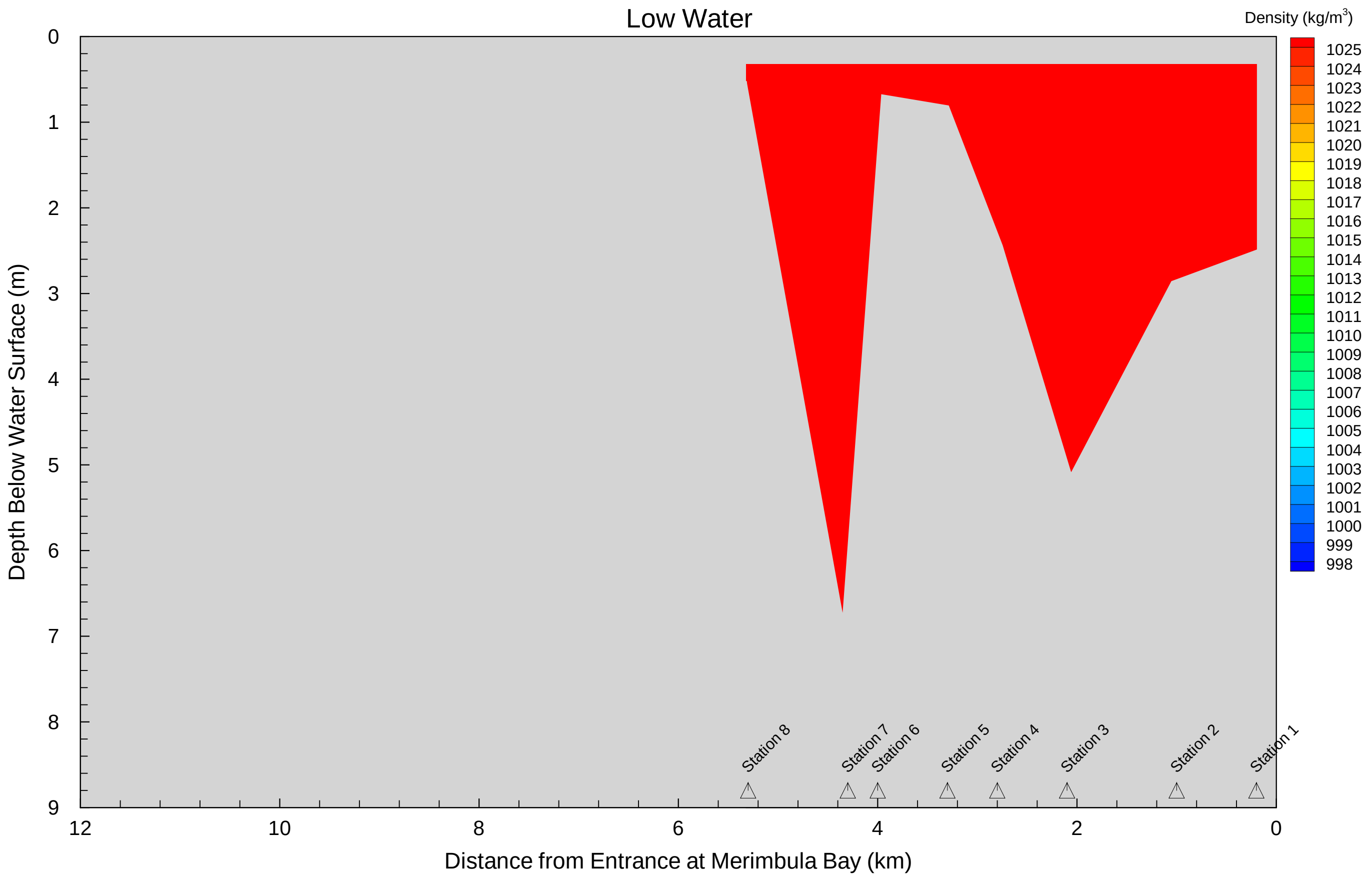


NSW Department of Commerce MANLY HYDRAULICS LABORATORY	SITE 15 - YOWAKA RIVER CONTOURS OF LONG CHANNEL VELOCITY PEAK DISCHARGE - 25 OCTOBER 2003	MHL Report 1290 Figure C12 DRAWING 1290C012.BPS

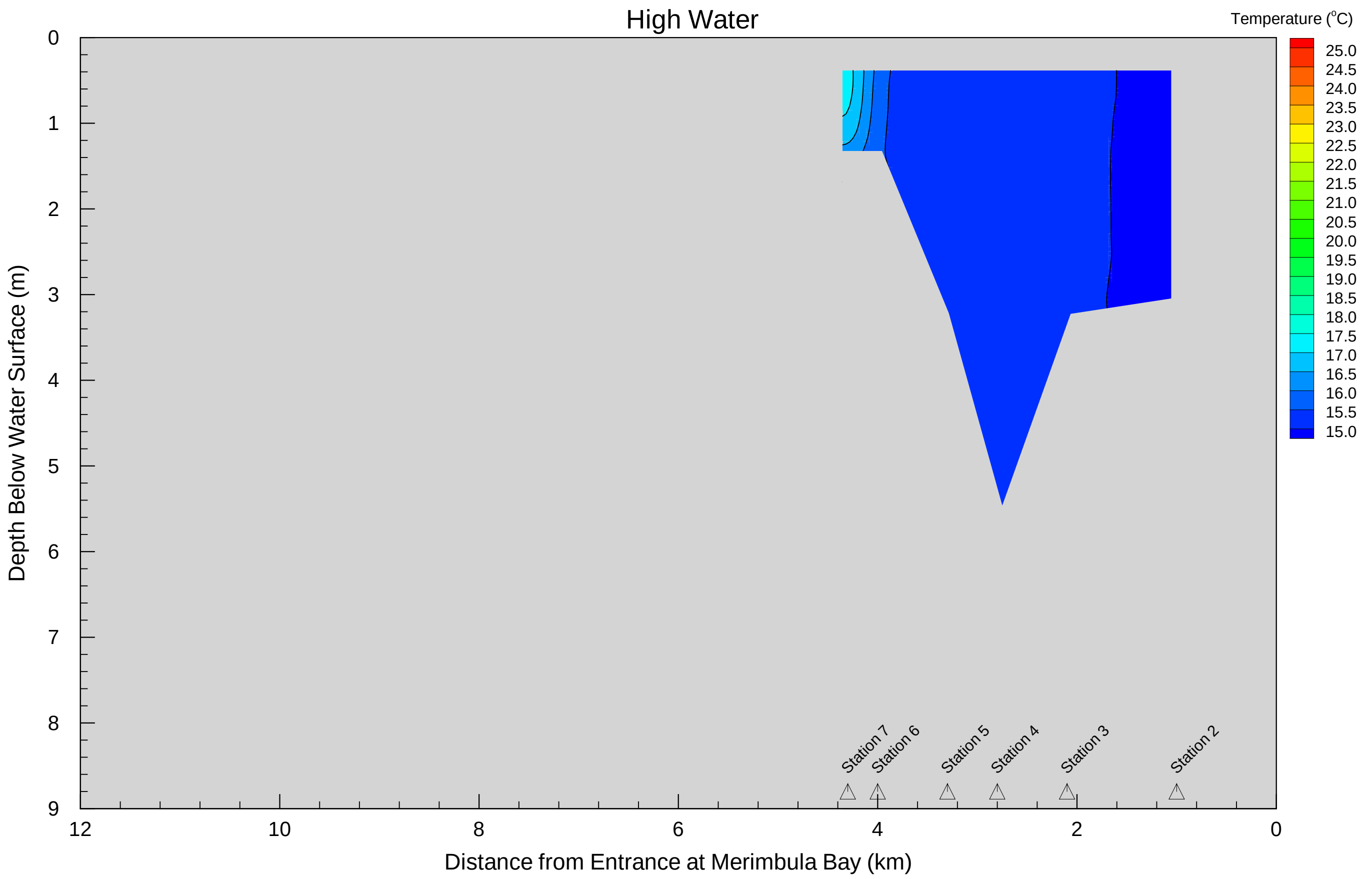
Appendix D

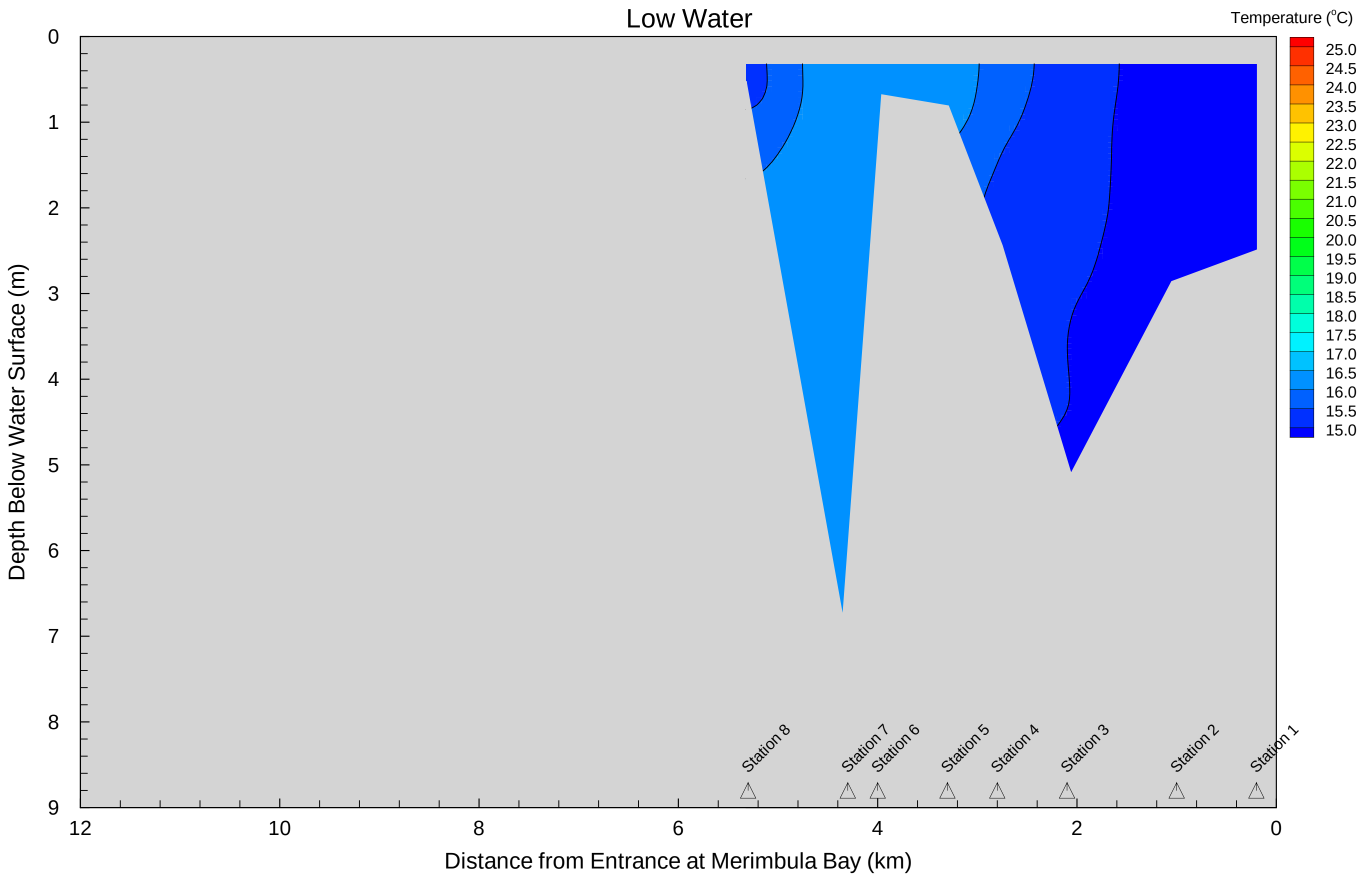
Water Quality Contour Data





NSW Department of Commerce MANLY HYDRAULICS LABORATORY	MERIMBULA LAKE LONG CHANNEL DENSITY CONTOURS 27 AND 30 OCTOBER 2003	MHL Report 1290 Figure D1 DRAWING 1290D001.BPS





NSW Department of Commerce

MANLY HYDRAULICS LABORATORY

MERIMBULA LAKE

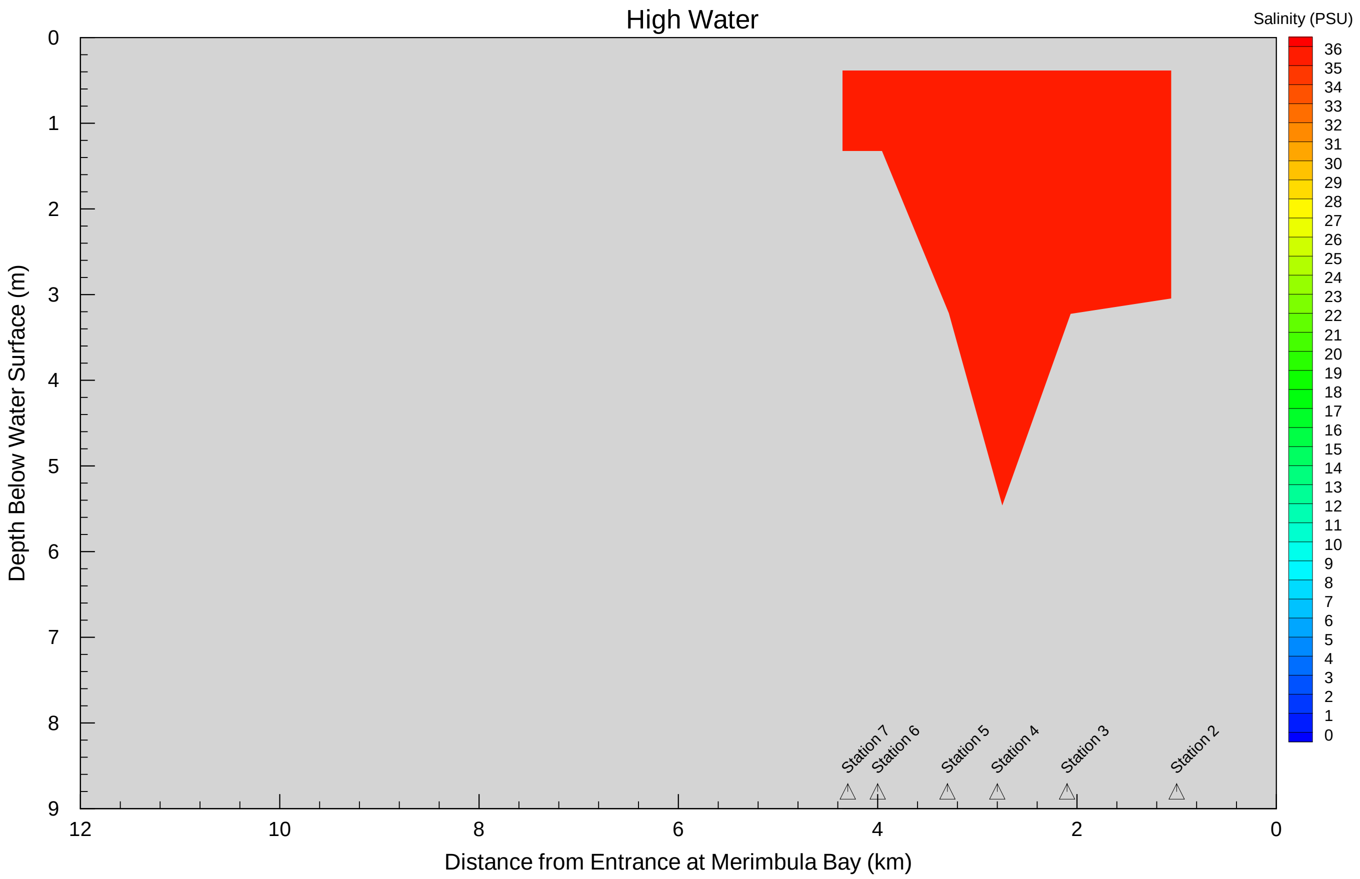
LONG CHANNEL TEMPERATURE CONTOURS

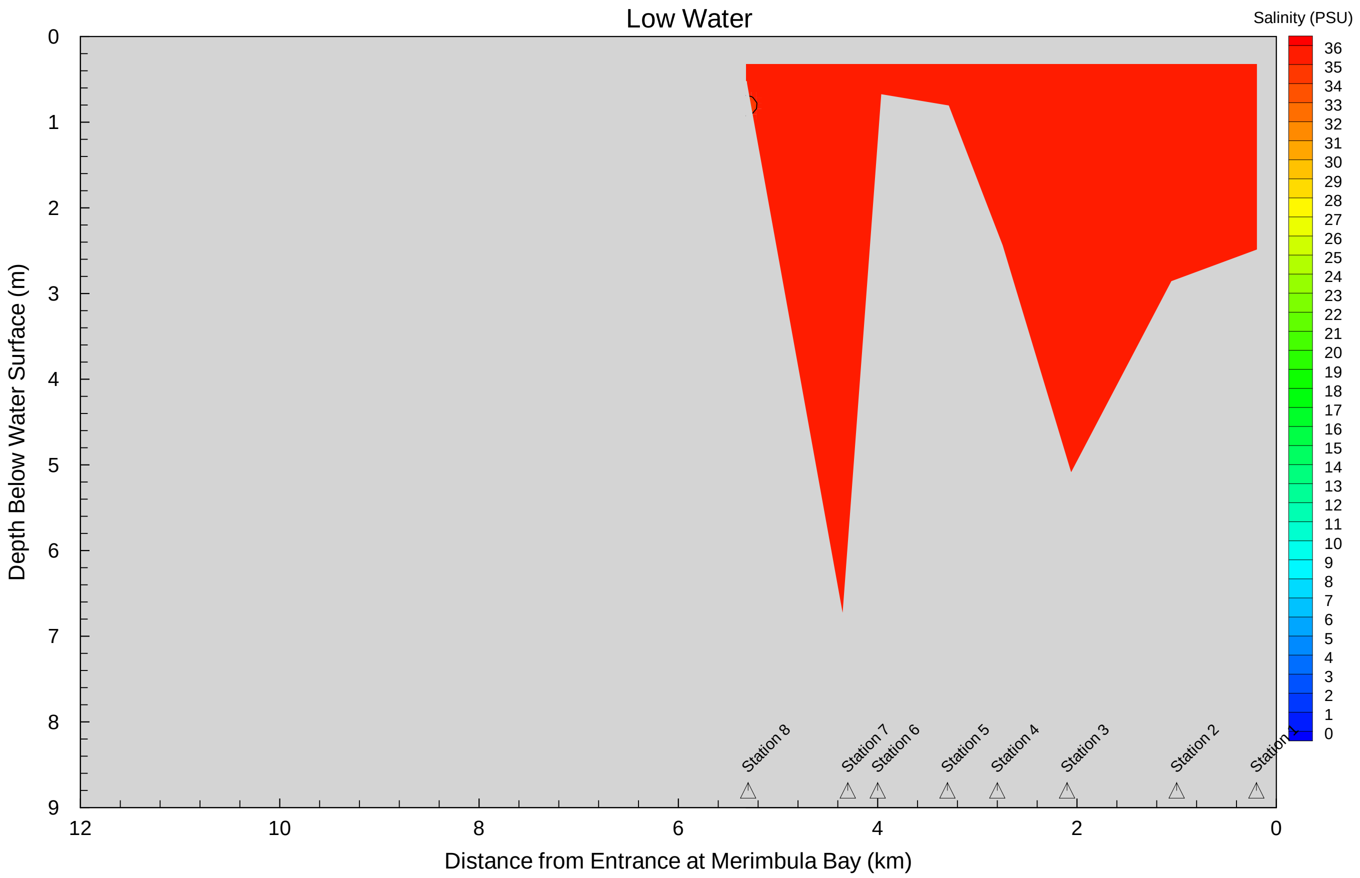
27 AND 30 OCTOBER 2003

MHL Report 1290

Figure D2

DRAWING 1290D002.BPS





NSW Department of Commerce

MANLY HYDRAULICS LABORATORY

MERIMBULA LAKE

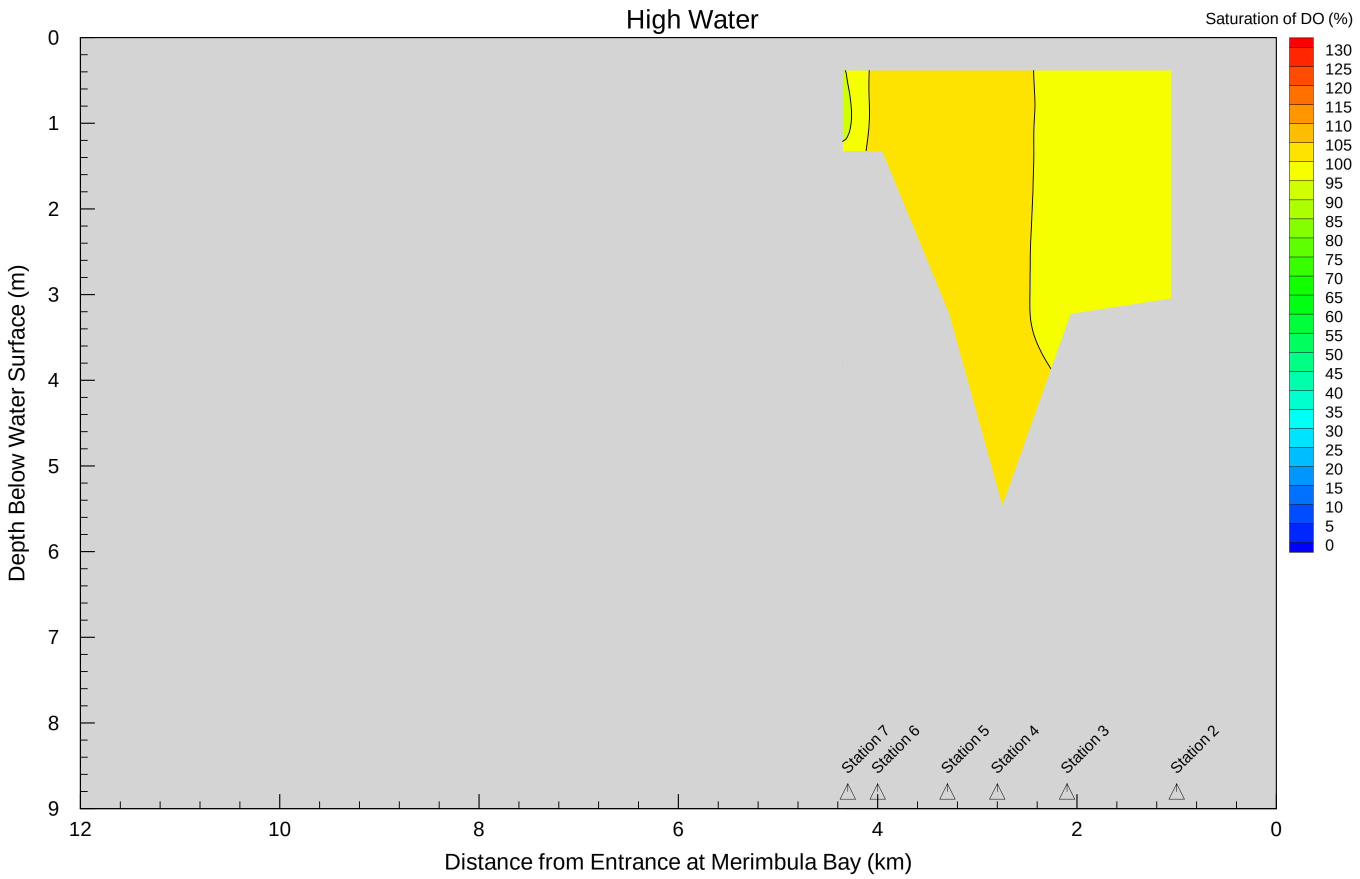
LONG CHANNEL SALINITY CONTOURS

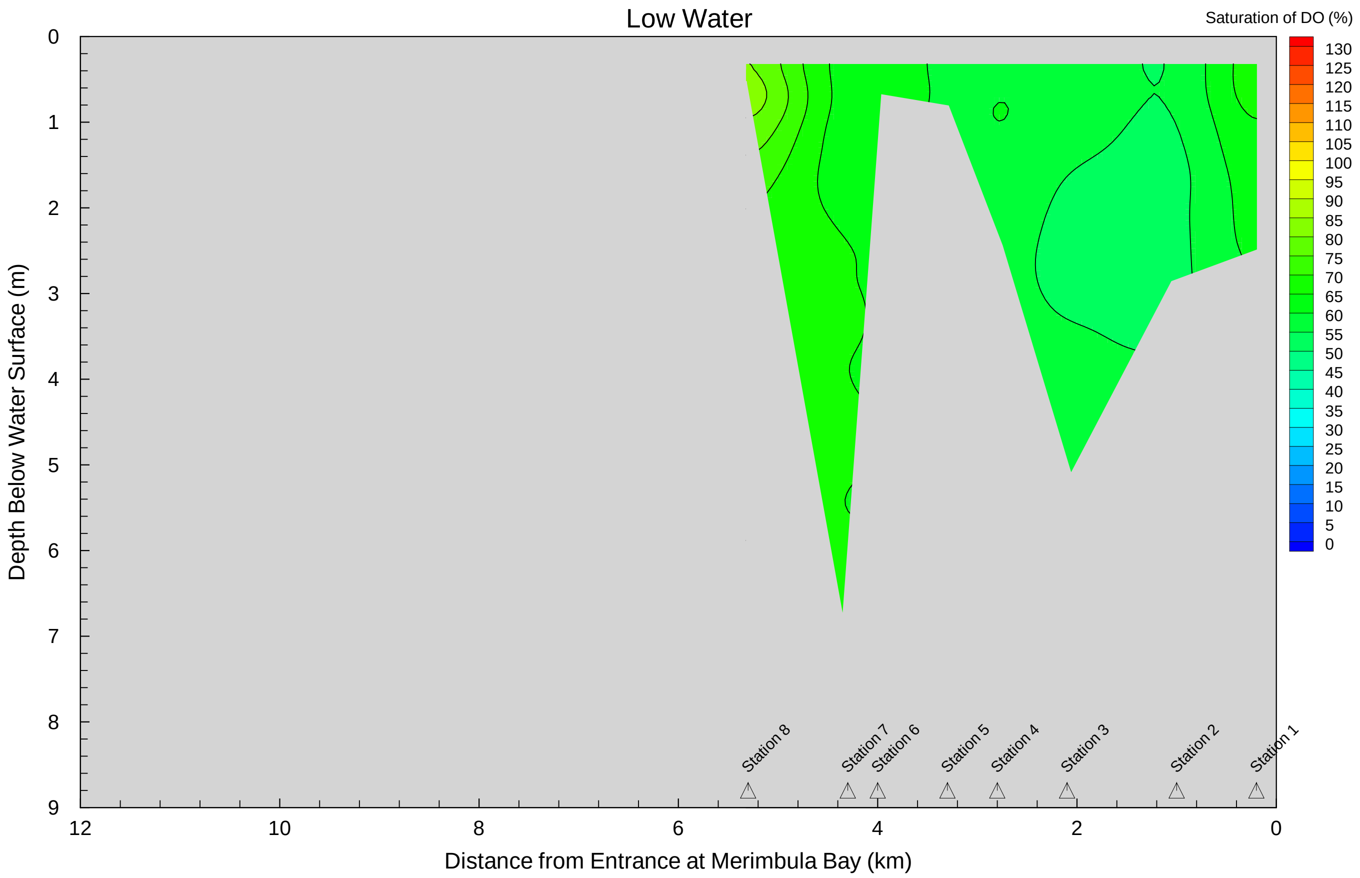
27 AND 30 OCTOBER 2003

MHL Report 1290

Figure D3

DRAWING 1290D003.BPS





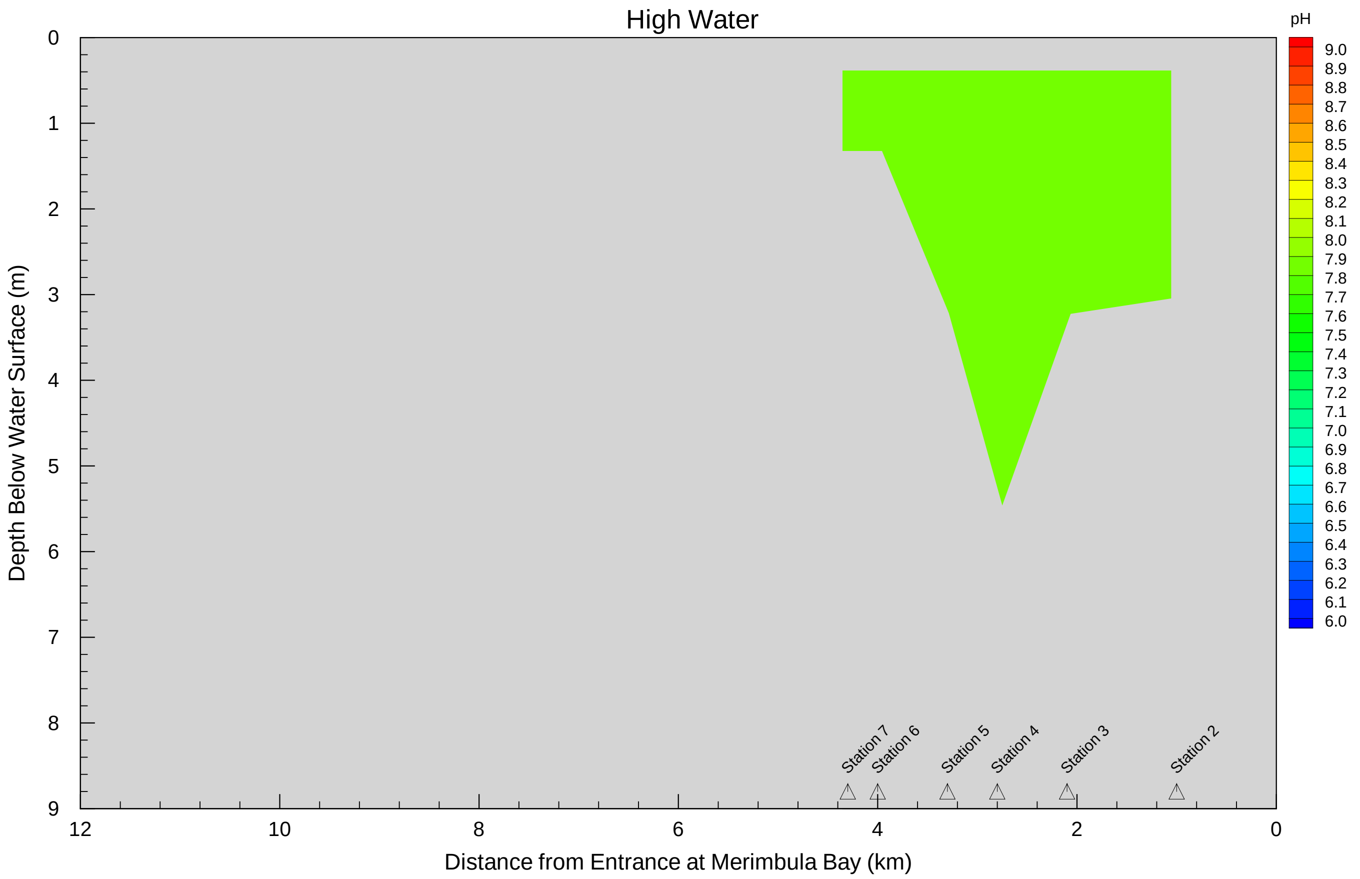
NSW Department of Commerce
MANLY HYDRAULICS LABORATORY

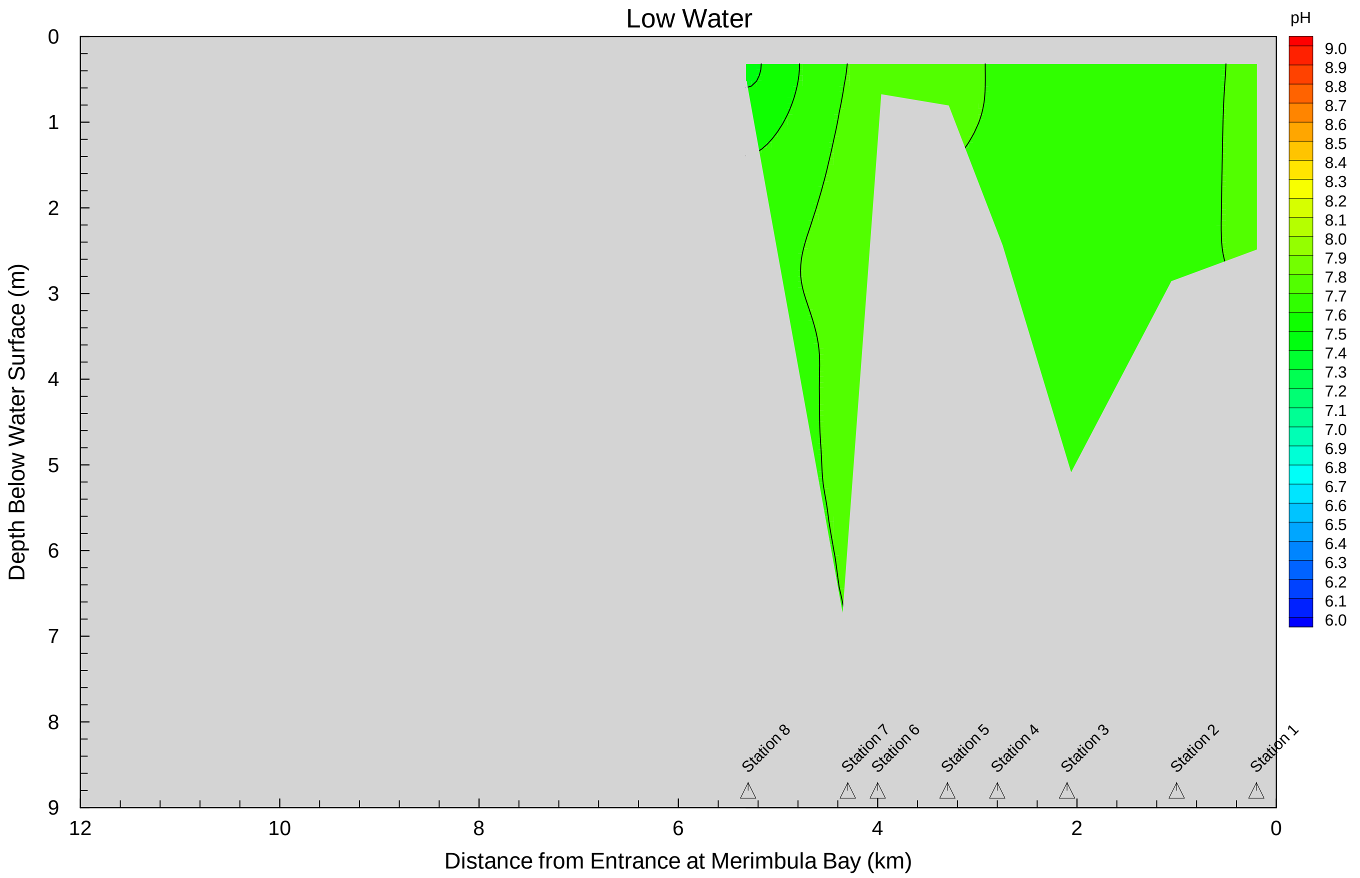
MERIMBULA LAKE
LONG CHANNEL % SATURATION OF DO CONTOURS
27 AND 30 OCTOBER 2003

MHL Report 1290

Figure D4

DRAWING 1290D004.BPS



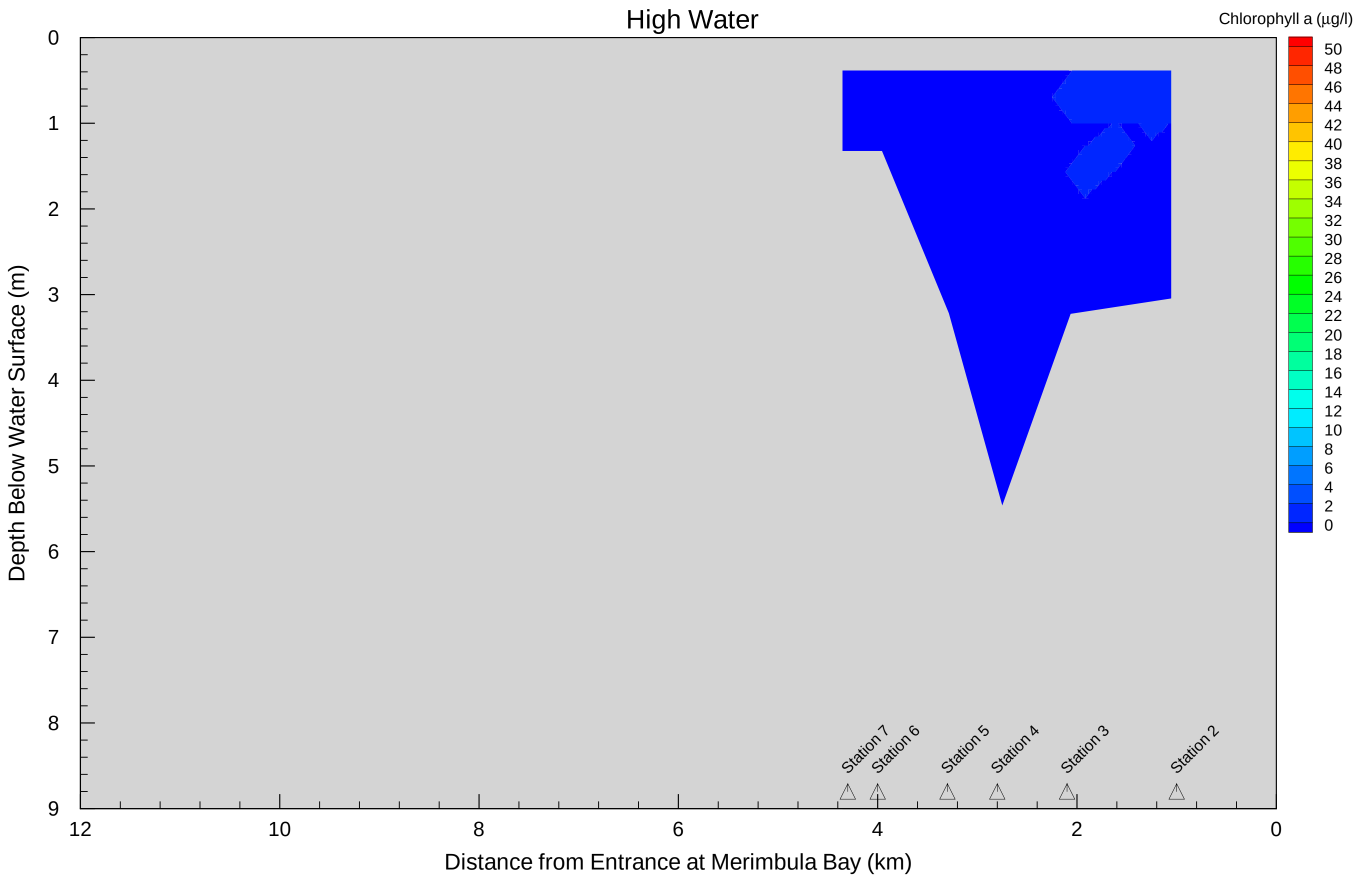


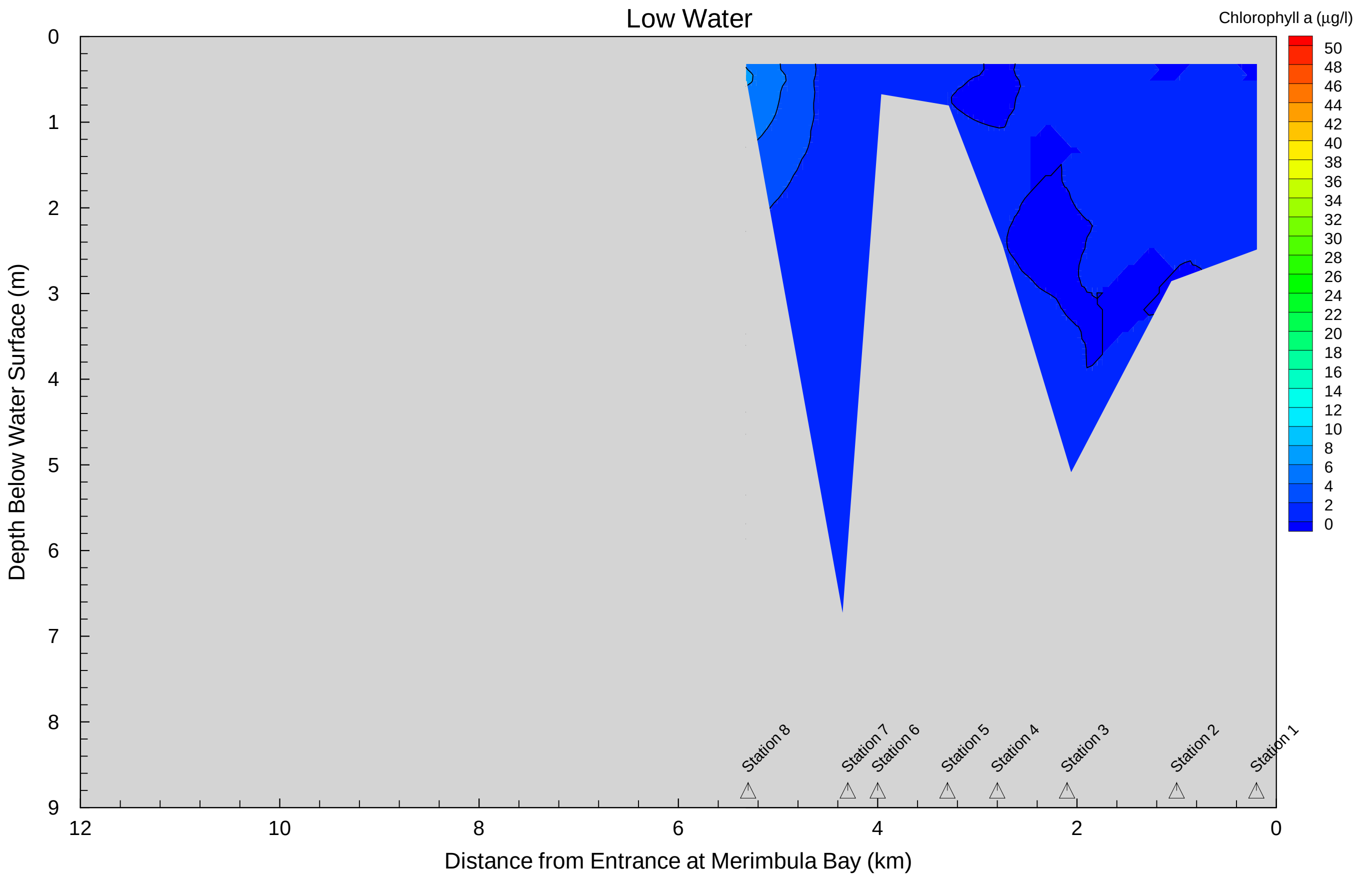
NSW Department of Commerce
MANLY HYDRAULICS LABORATORY

MERIMBULA LAKE
LONG CHANNEL pH CONTOURS
27 AND 30 OCTOBER 2003

MHL Report 1290
Figure D5

DRAWING 1290D005.BPS





NSW Department of Commerce

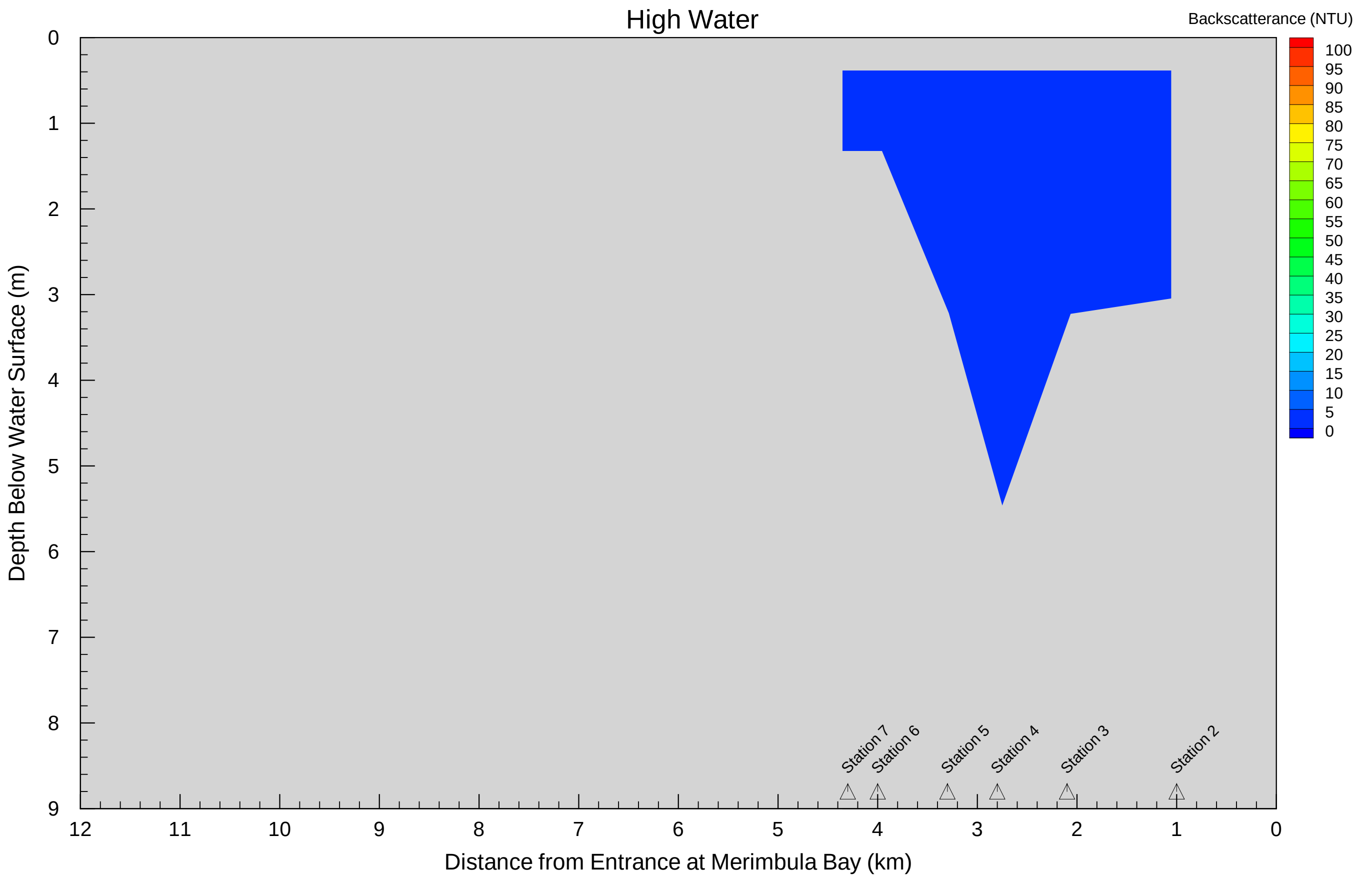
MANLY HYDRAULICS LABORATORY

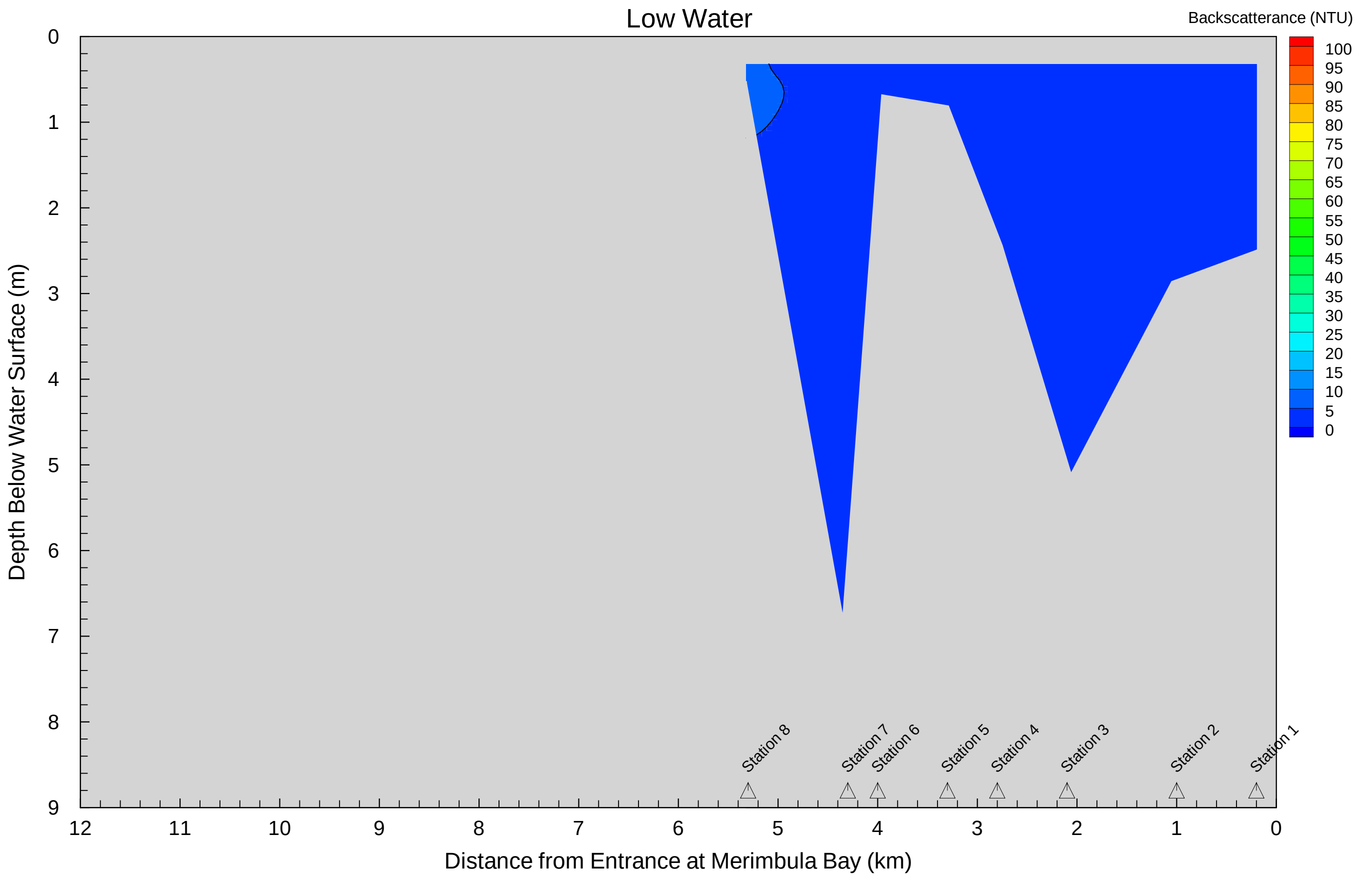
MERIMBULA LAKE
LONG CHANNEL CHLOROPHYLL-A CONTOURS
27 AND 30 OCTOBER 2003

MHL Report 1290

Figure D6

DRAWING 1290D006.BPS





NSW Department of Commerce

MANLY HYDRAULICS LABORATORY

MERIMBULA LAKE

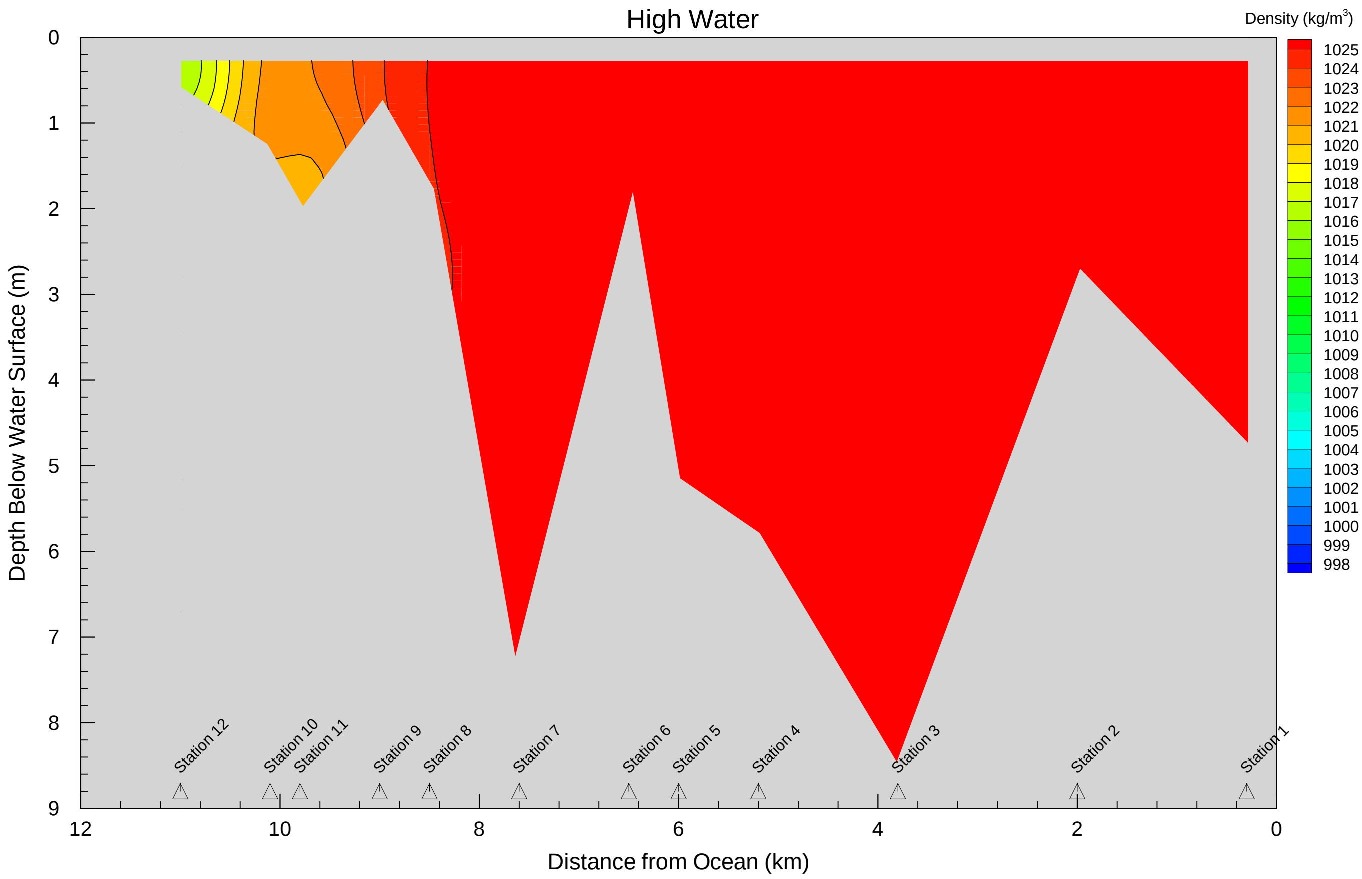
LONG CHANNEL BACKSCATTERANCE CONTOURS

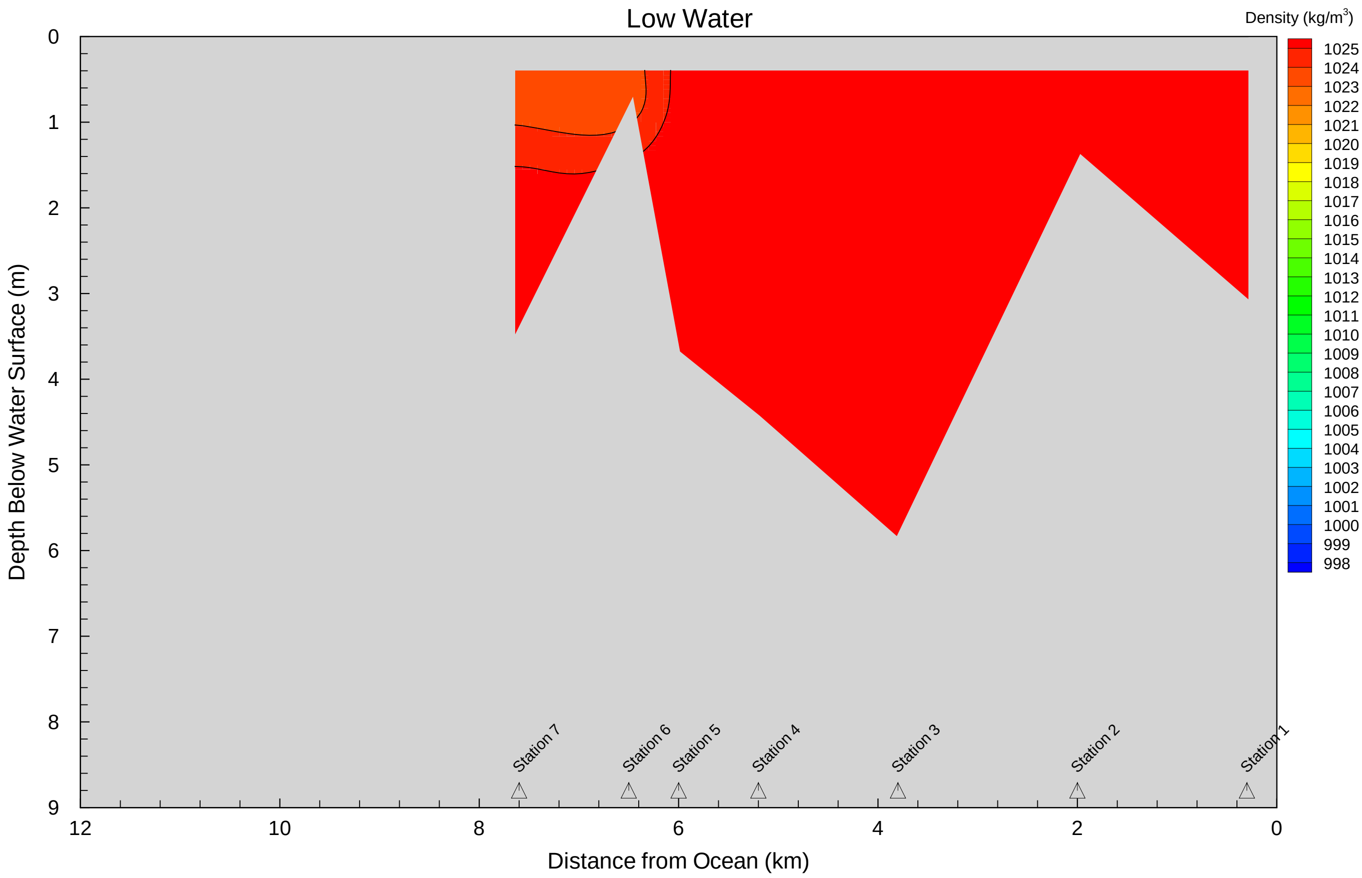
27 AND 30 OCTOBER 2003

MHL Report 1290

Figure D7

DRAWING 1290D007.BPS





NSW Department of Commerce

MANLY HYDRAULICS LABORATORY

PAMBULA LAKE

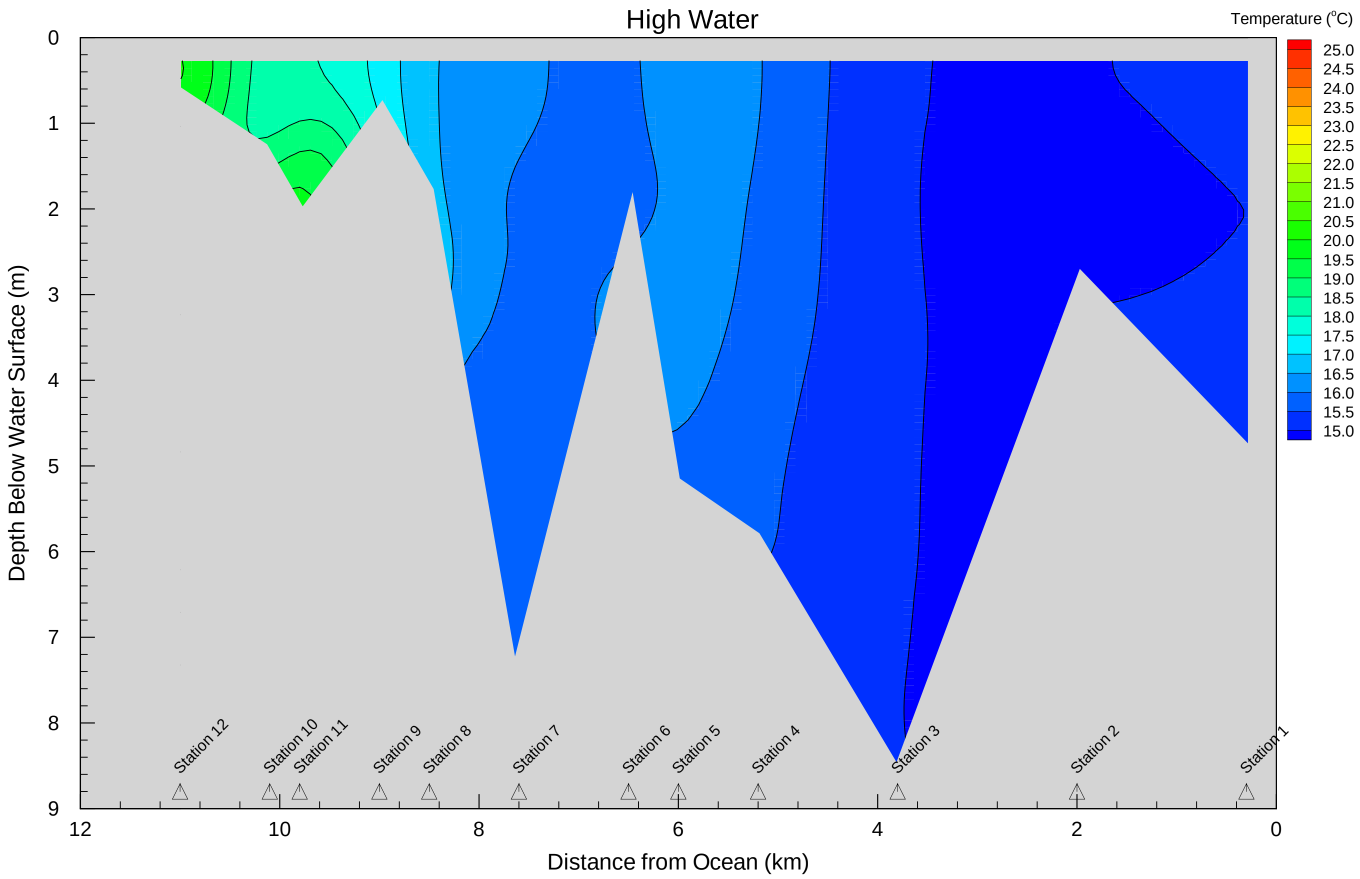
LONG CHANNEL DENSITY CONTOURS

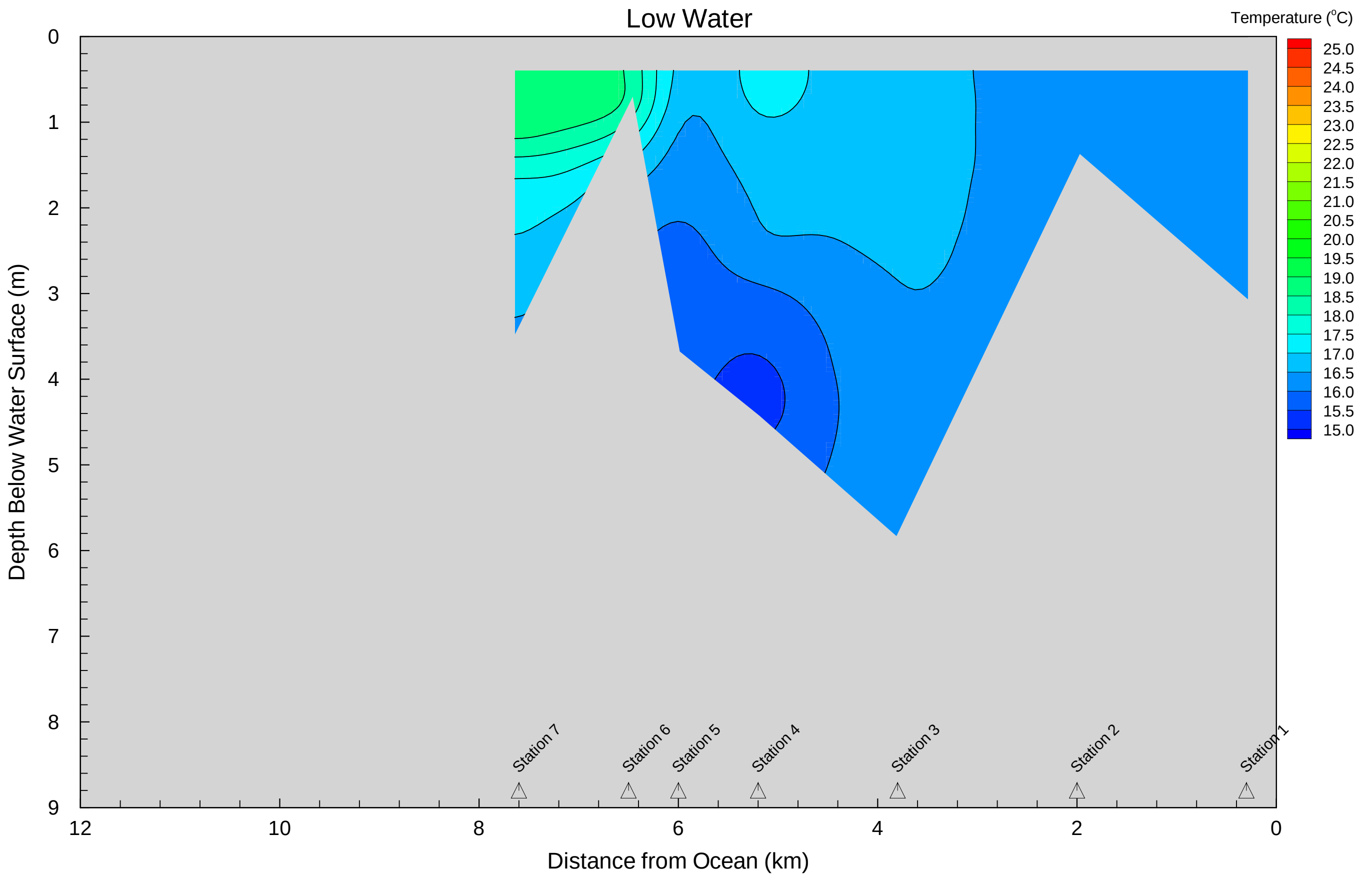
27 AND 28 OCTOBER 2003

MHL Report 1290

Figure D8

DRAWING 1290D008.BPS





NSW Department of Commerce

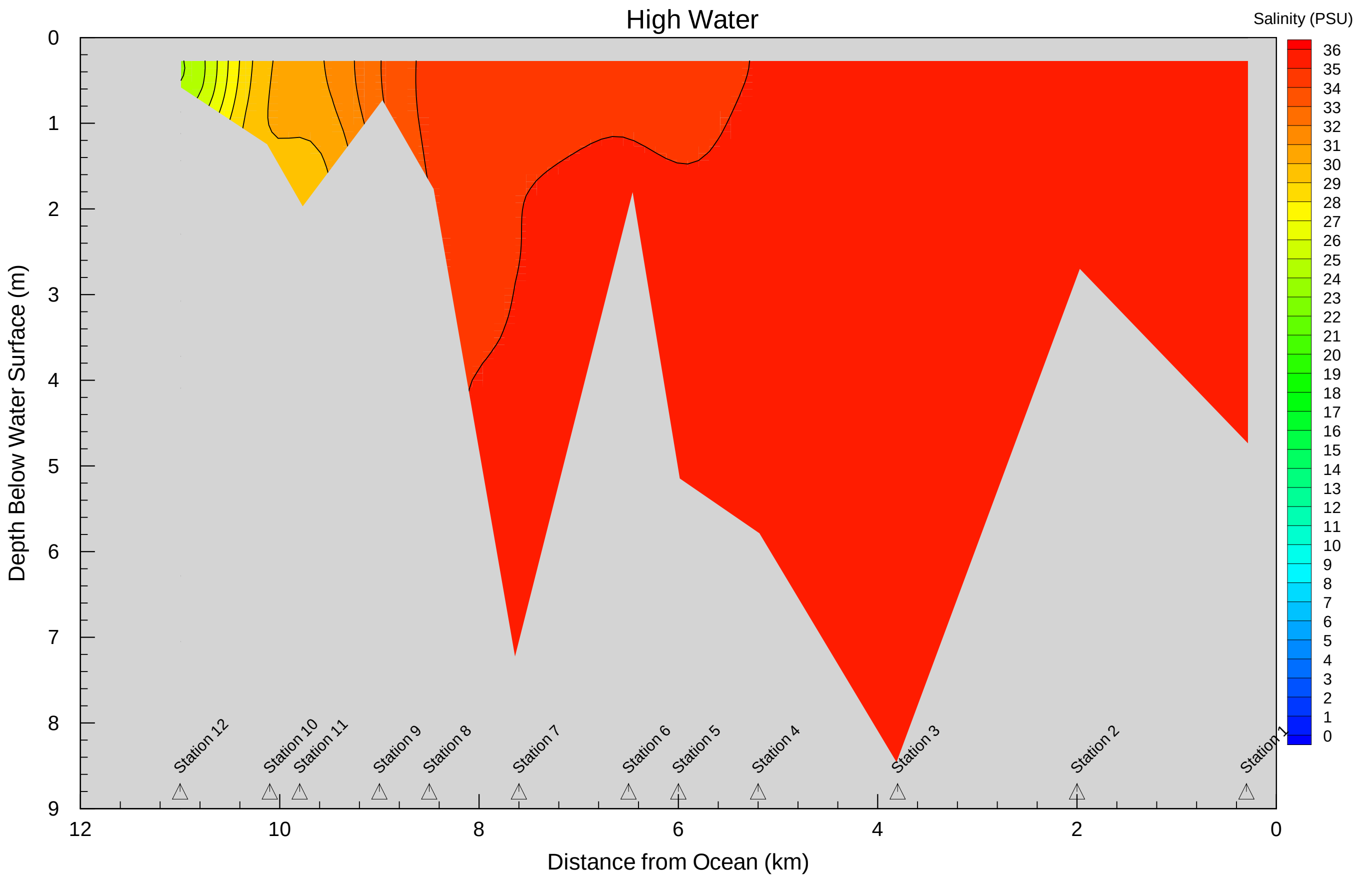
MANLY HYDRAULICS LABORATORY

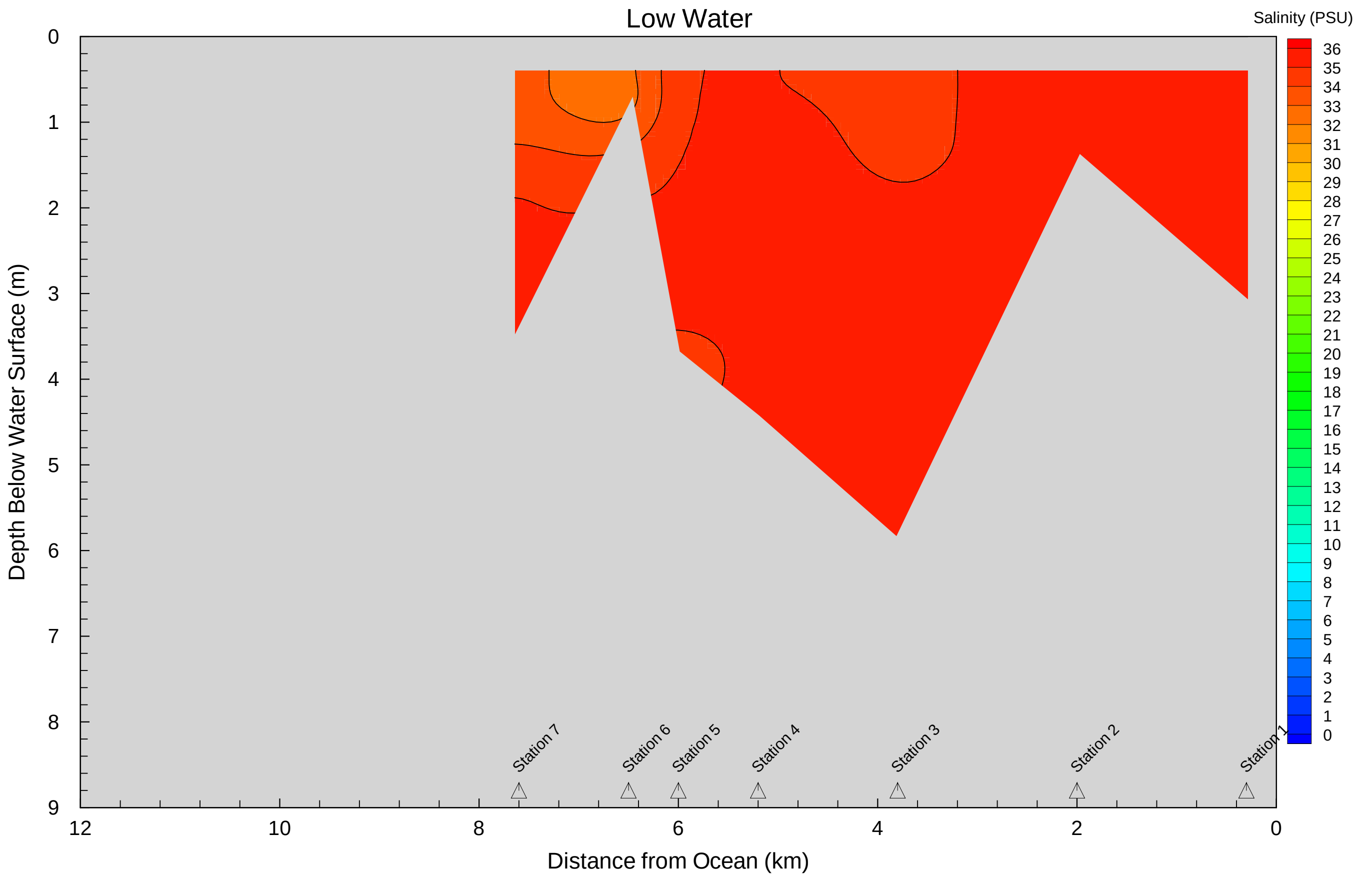
PAMBULA LAKE
LONG CHANNEL TEMPERATURE CONTOURS
27 AND 28 OCTOBER 2003

MHL Report 1290

Figure D9

DRAWING 1290D009.BPS





NSW Department of Commerce

MANLY HYDRAULICS LABORATORY

PAMBULA LAKE

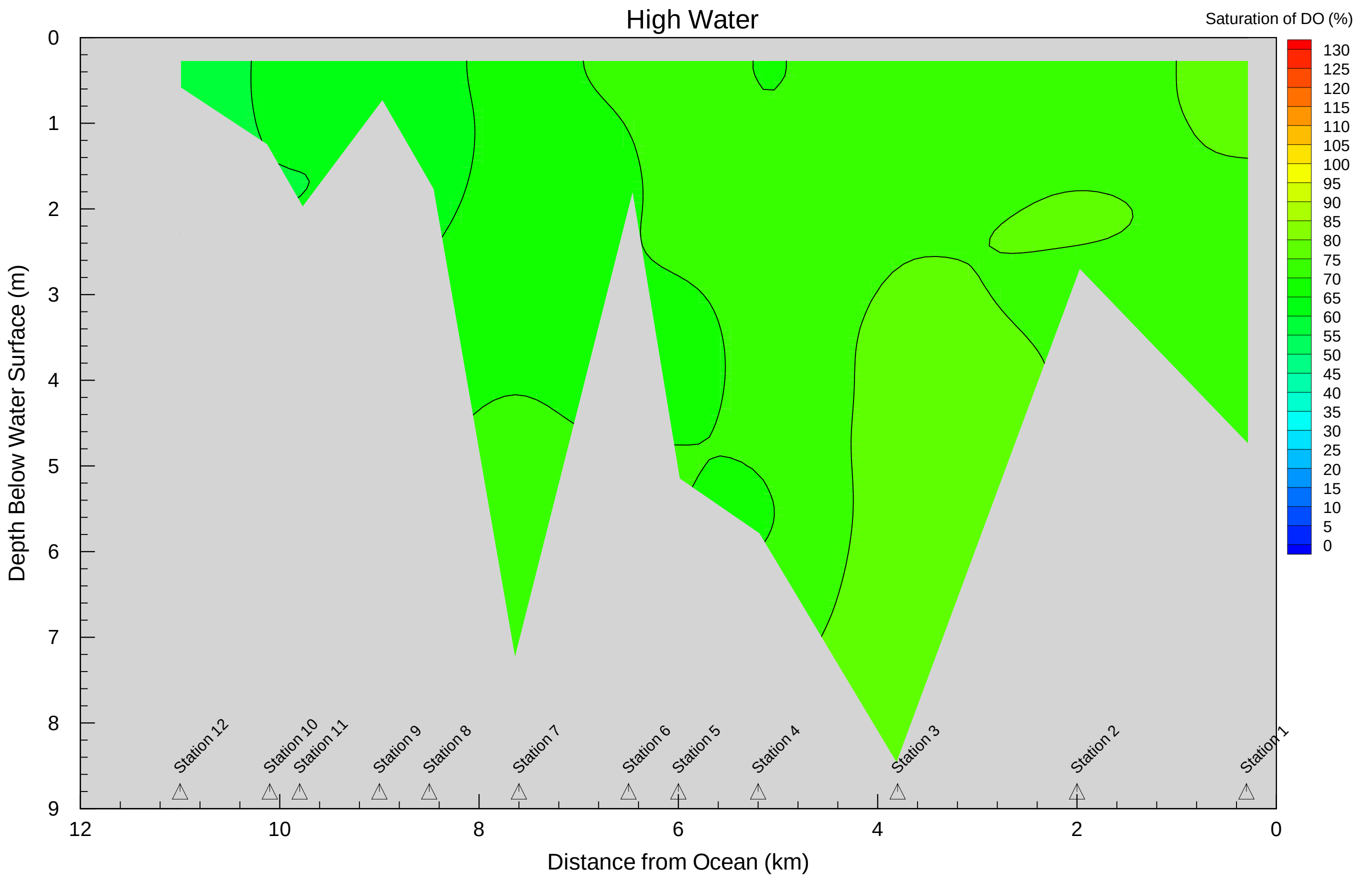
LONG CHANNEL SALINITY CONTOURS

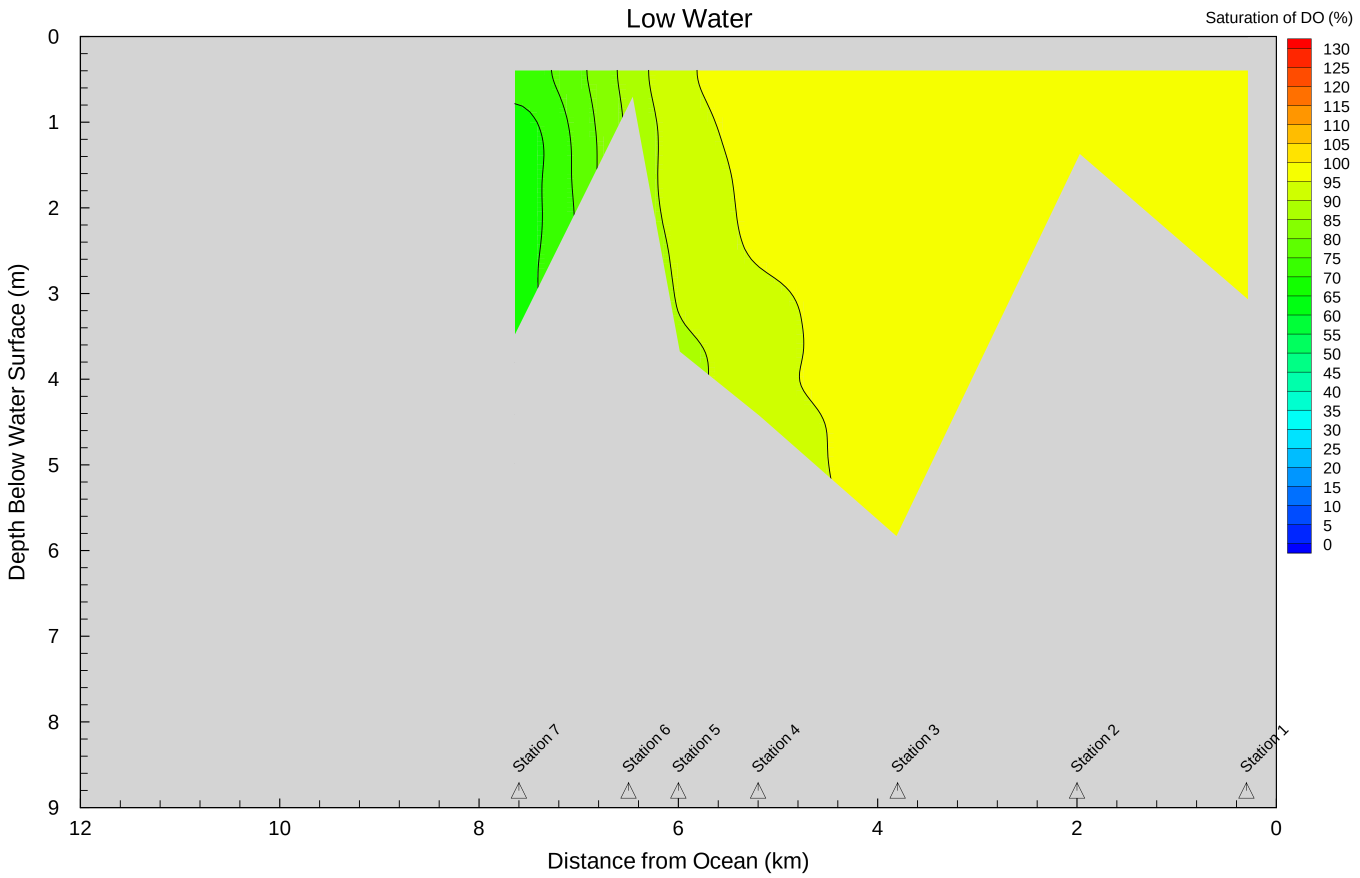
27 AND 28 OCTOBER 2003

MHL Report 1290

Figure D10

DRAWING 1290D010.BPS





NSW Department of Commerce

MANLY HYDRAULICS LABORATORY

PAMBULA LAKE

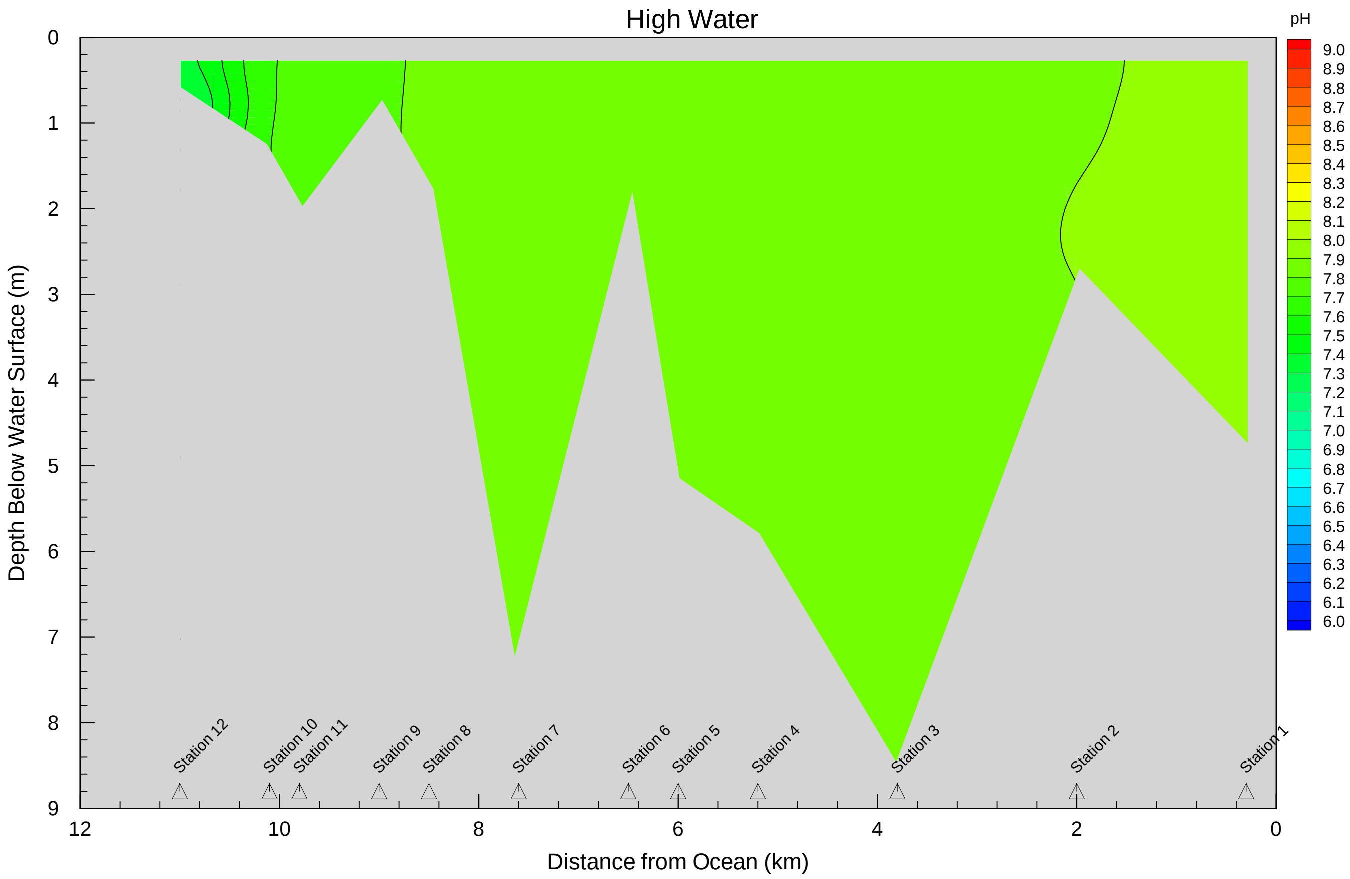
LONG CHANNEL % SATURATION OF DO CONTOURS

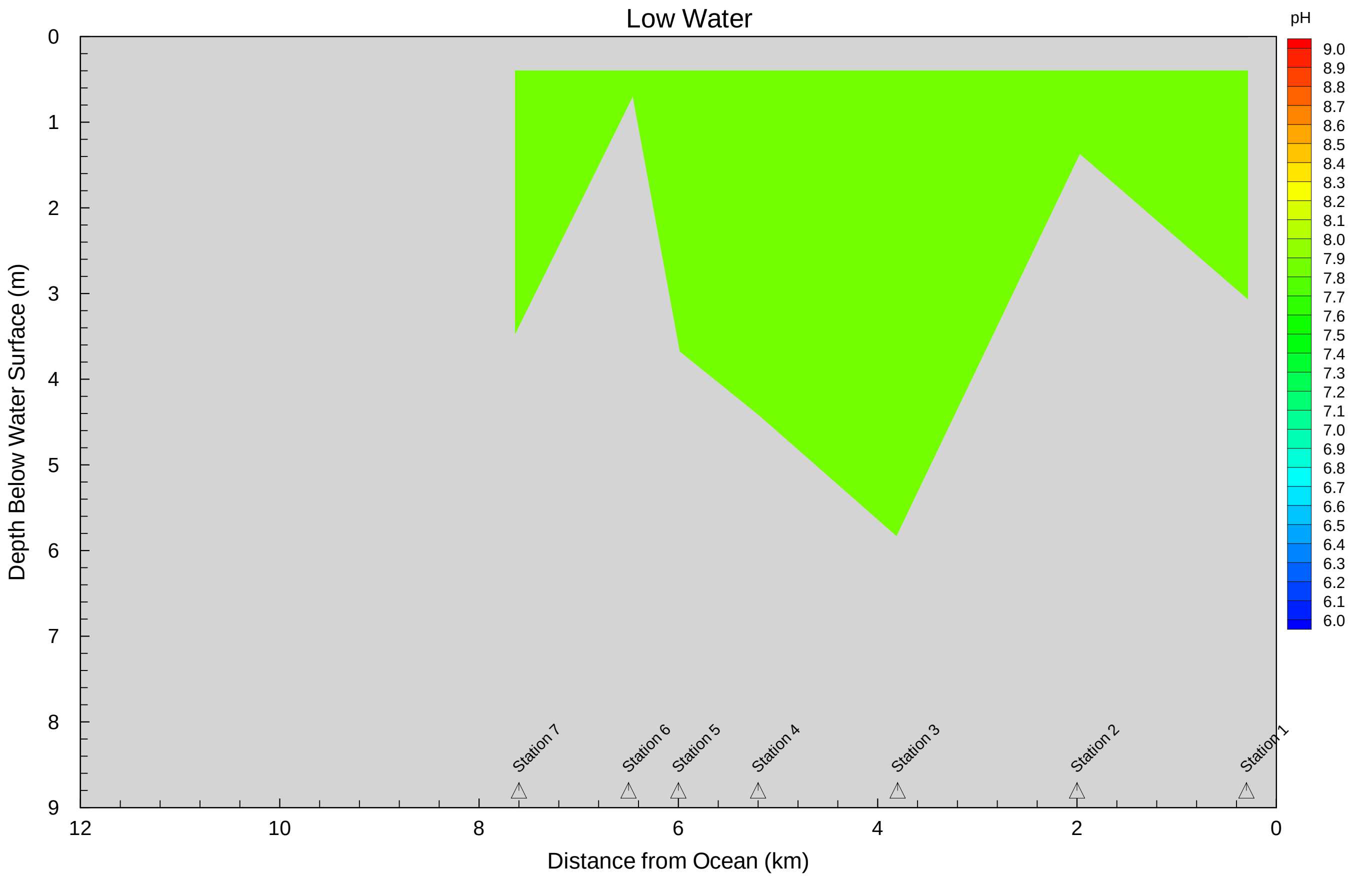
27 AND 28 OCTOBER 2003

MHL Report 1290

Figure D11

DRAWING 1290D011.BPS





NSW Department of Commerce

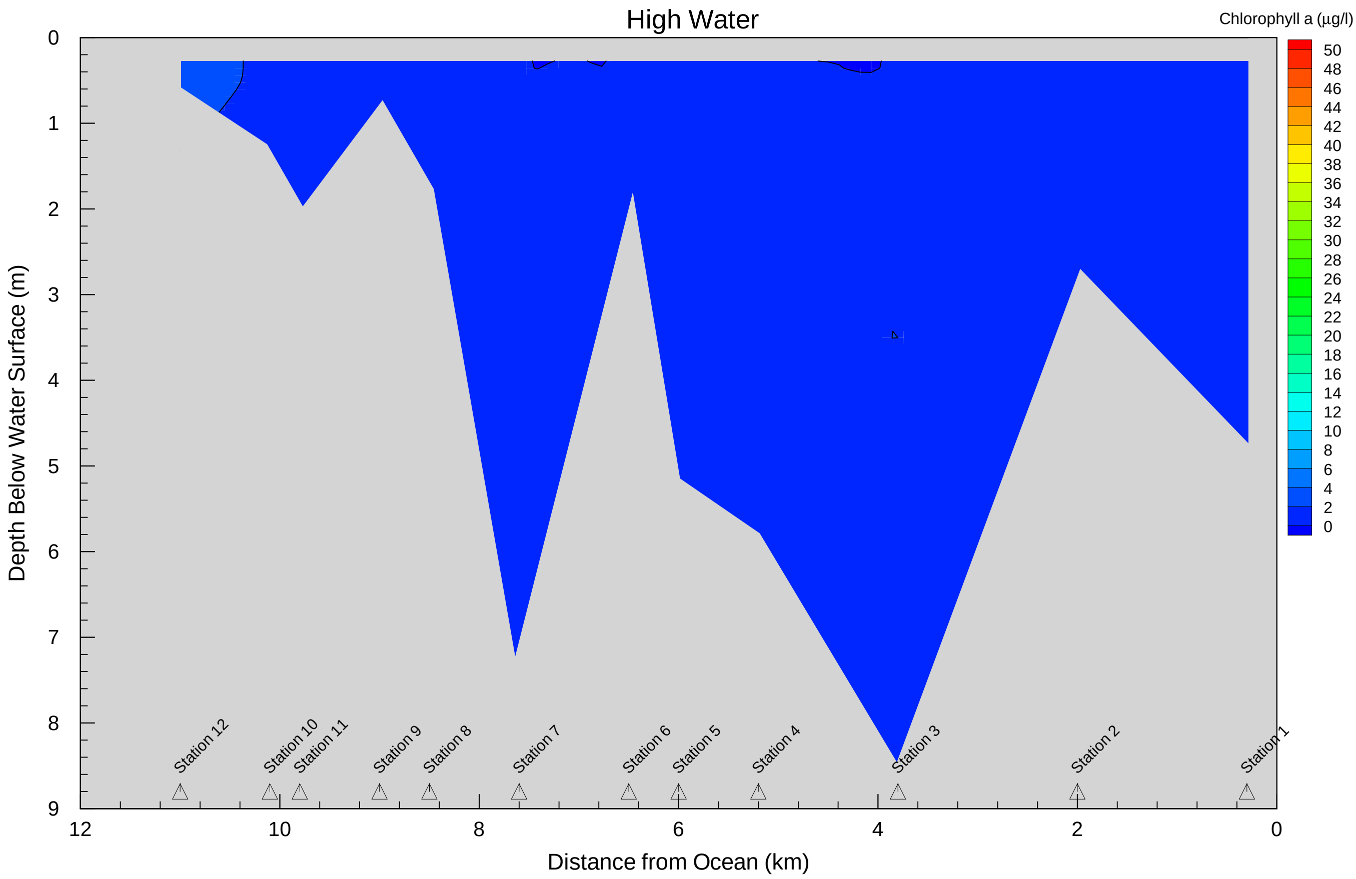
MANLY HYDRAULICS LABORATORY

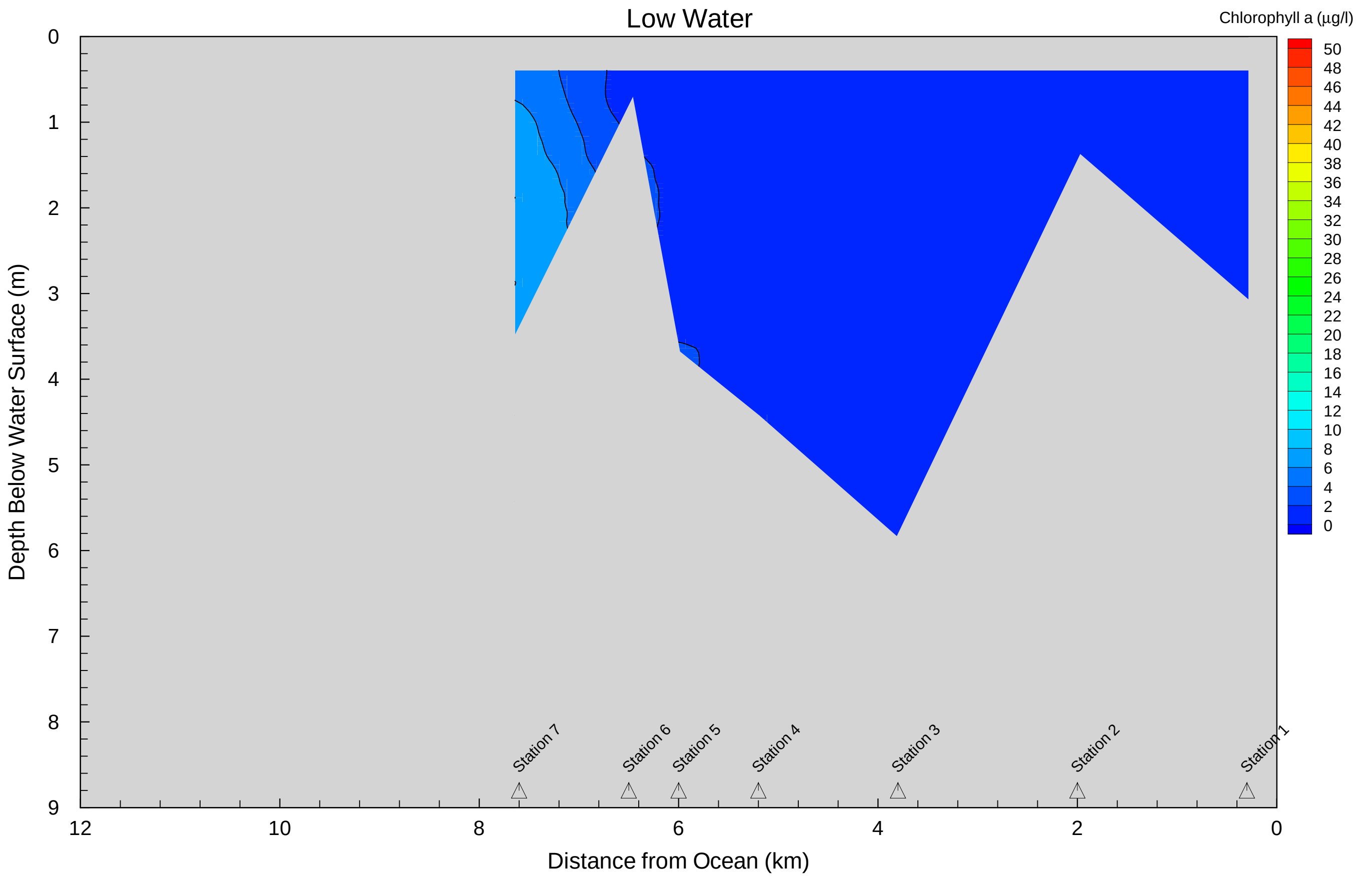
PAMBULA LAKE
LONG CHANNEL pH CONTOURS
27 AND 28 OCTOBER 2003

MHL Report 1290

Figure D12

DRAWING 1290D012.BPS





NSW Department of Commerce

MANLY HYDRAULICS LABORATORY

PAMBULA LAKE

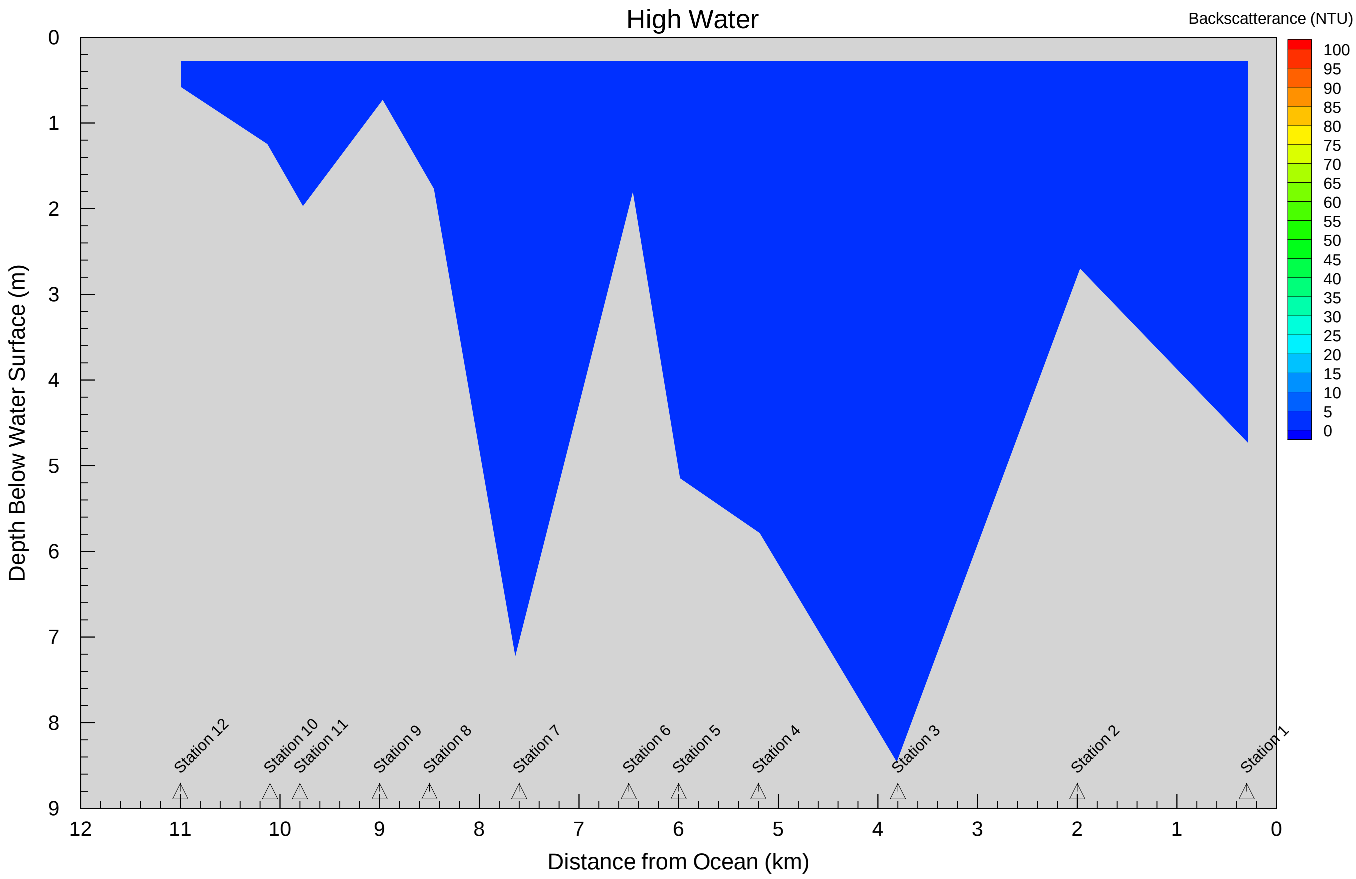
LONG CHANNEL CHLOROPHYLL-A CONTOURS

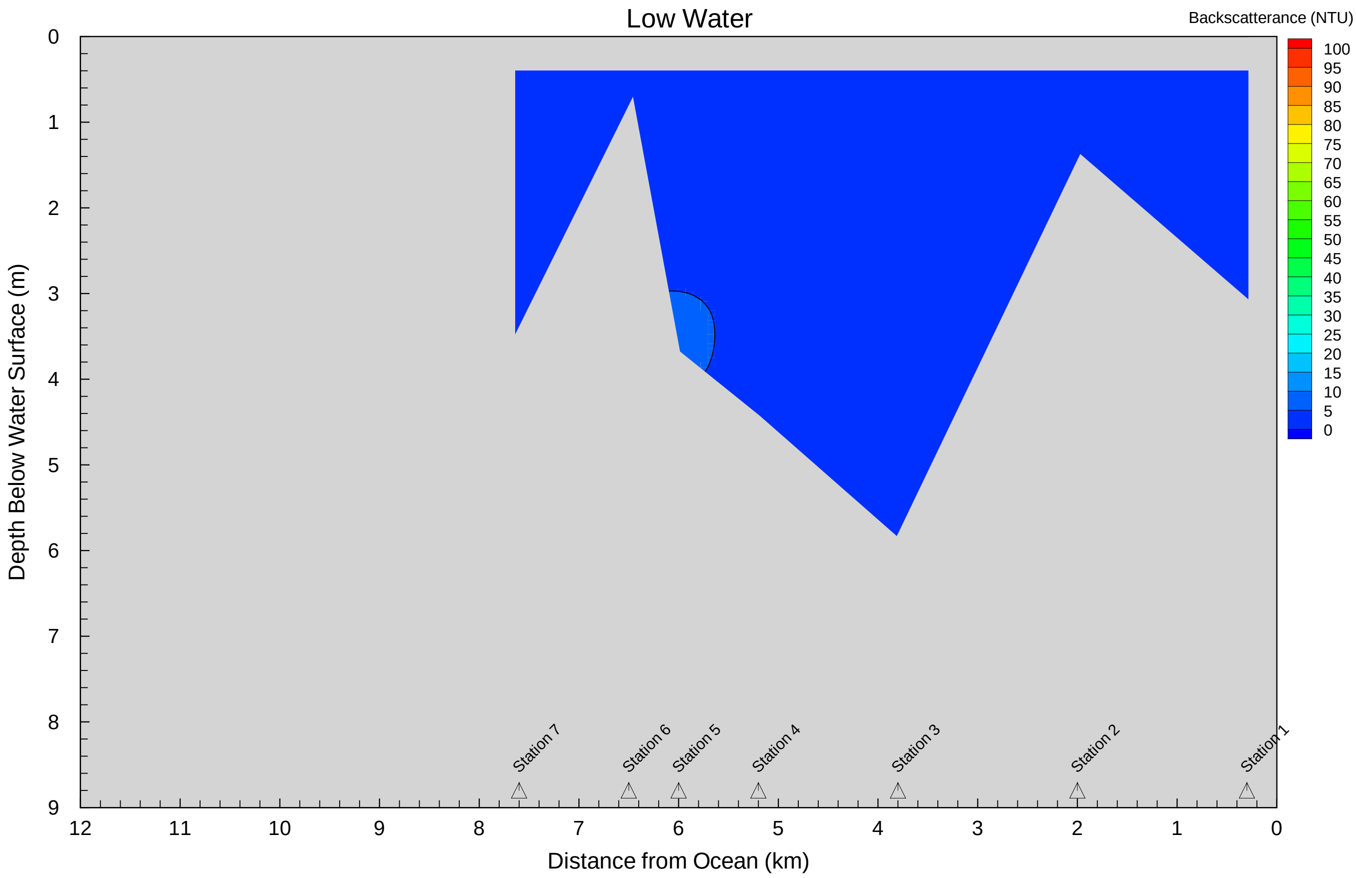
27 AND 28 OCTOBER 2003

MHL Report 1290

Figure D13

DRAWING 1290D013.BPS





NSW Department of Commerce

MANLY HYDRAULICS LABORATORY

PAMBULA LAKE

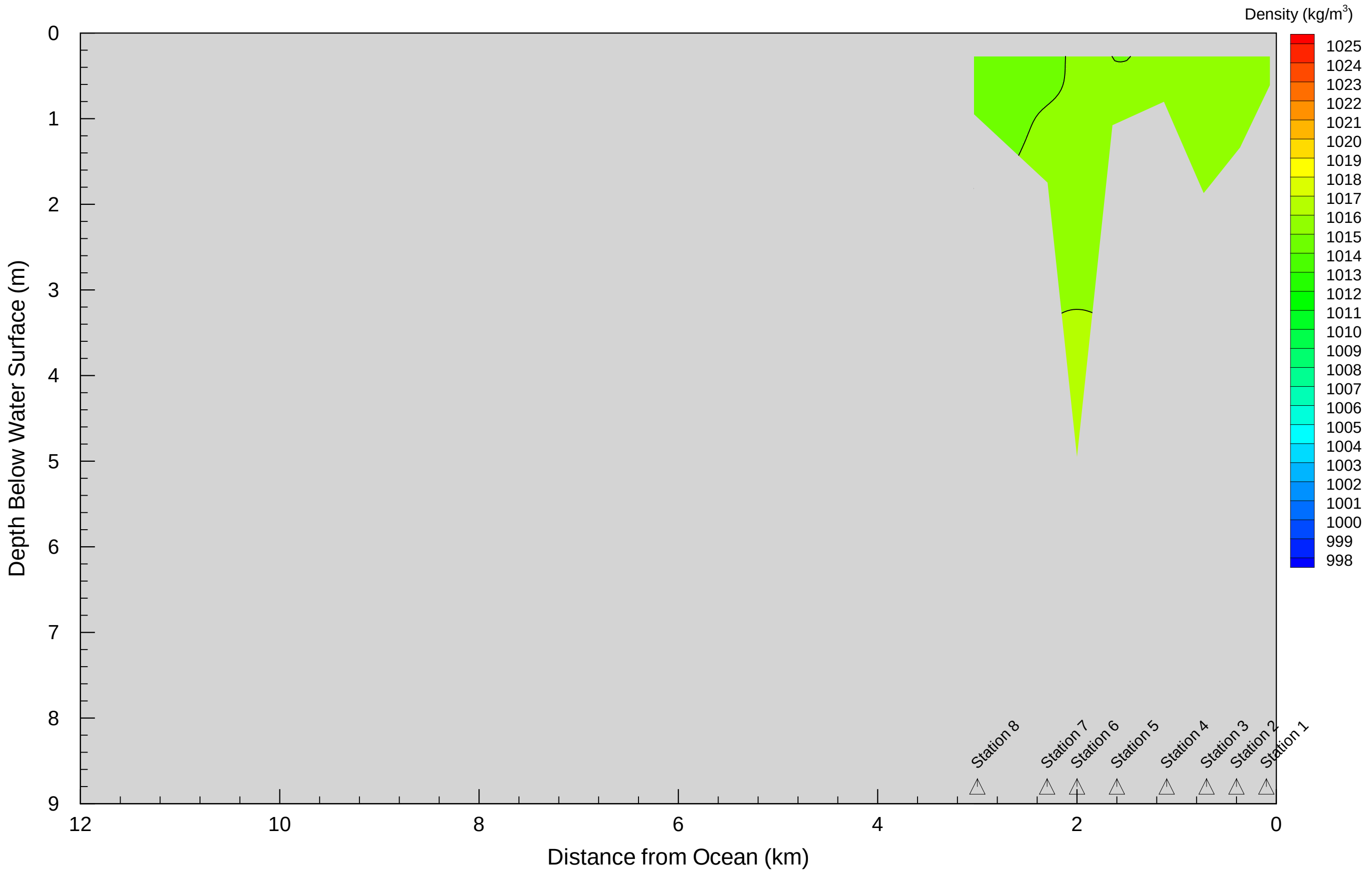
LONG CHANNEL BACKSCATTERANCE CONTOURS

27 AND 28 OCTOBER 2003

MHL Report 1290

Figure D14

DRAWING 1290D014.BPS



NSW Department of Commerce

MANLY HYDRAULICS LABORATORY

BACK LAGOON

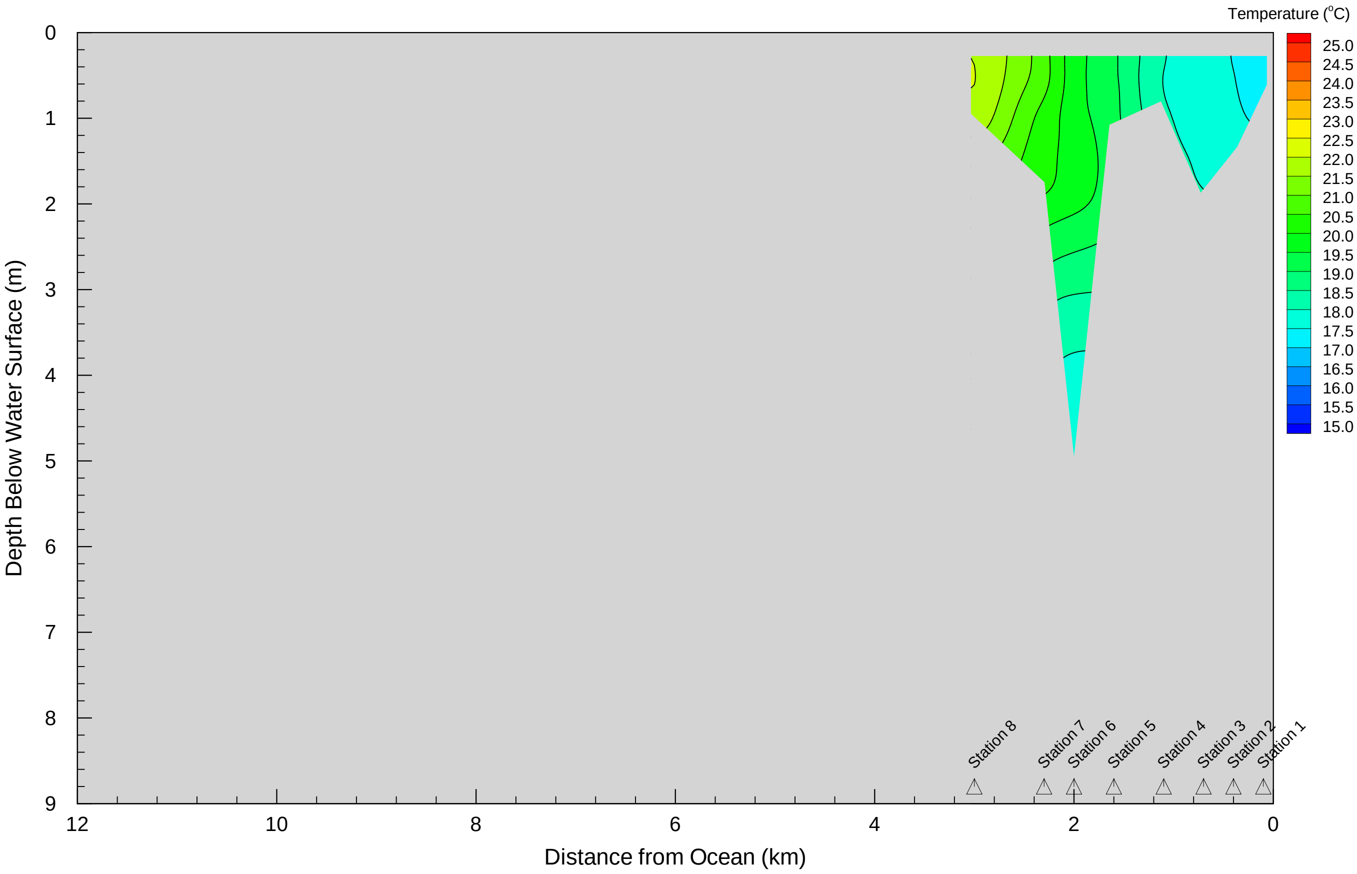
LONG CHANNEL DENSITY CONTOURS

26 OCTOBER 2003

MHL Report 1290

Figure D15

DRAWING 1290D015.BPS



NSW Department of Commerce

MANLY HYDRAULICS LABORATORY

BACK LAGOON

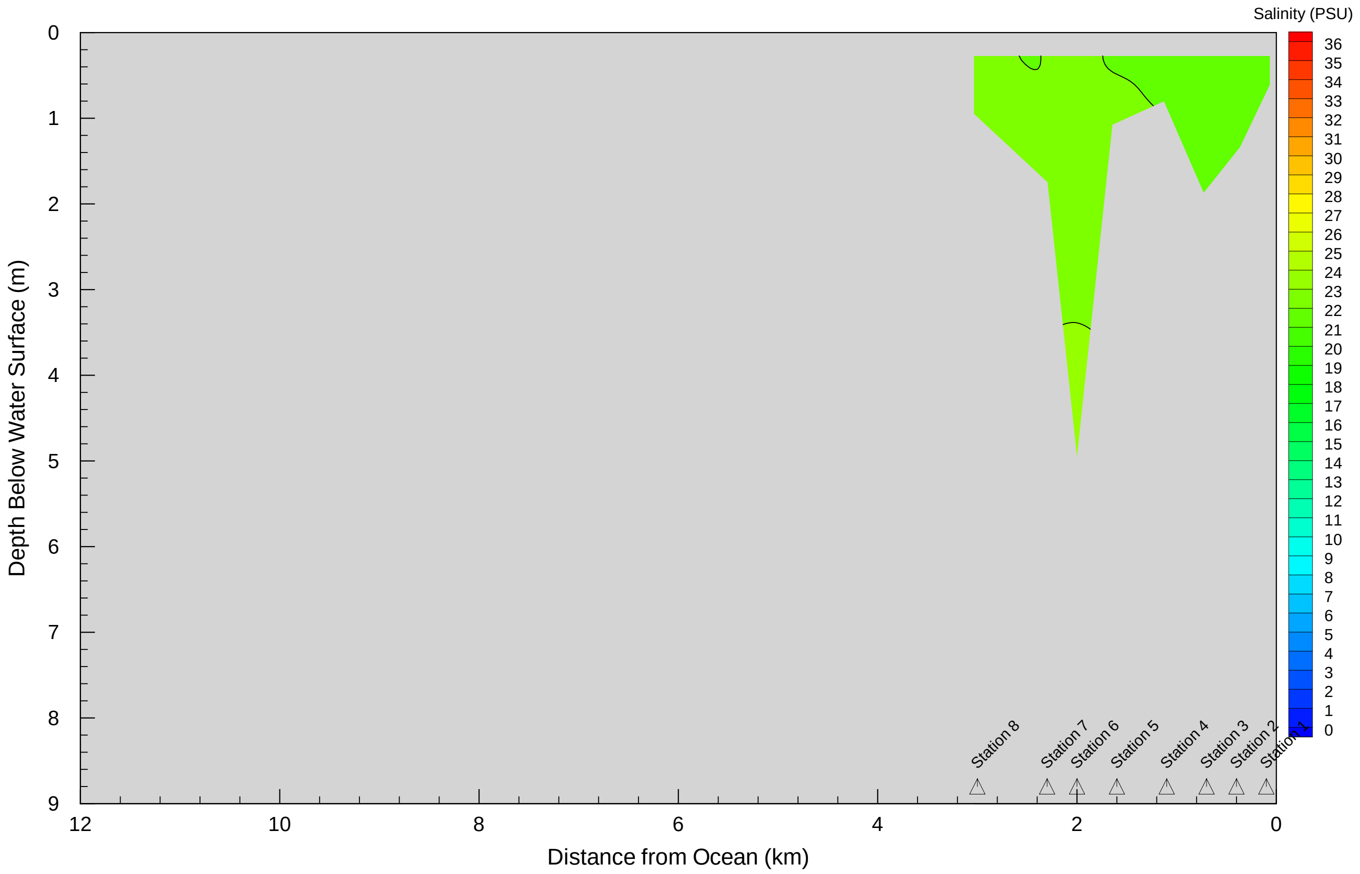
LONG CHANNEL TEMPERATURE CONTOURS

26 OCTOBER 2003

MHL Report 1290

Figure D16

DRAWING 1290D016.BPS



NSW Department of Commerce

MANLY HYDRAULICS LABORATORY

BACK LAGOON

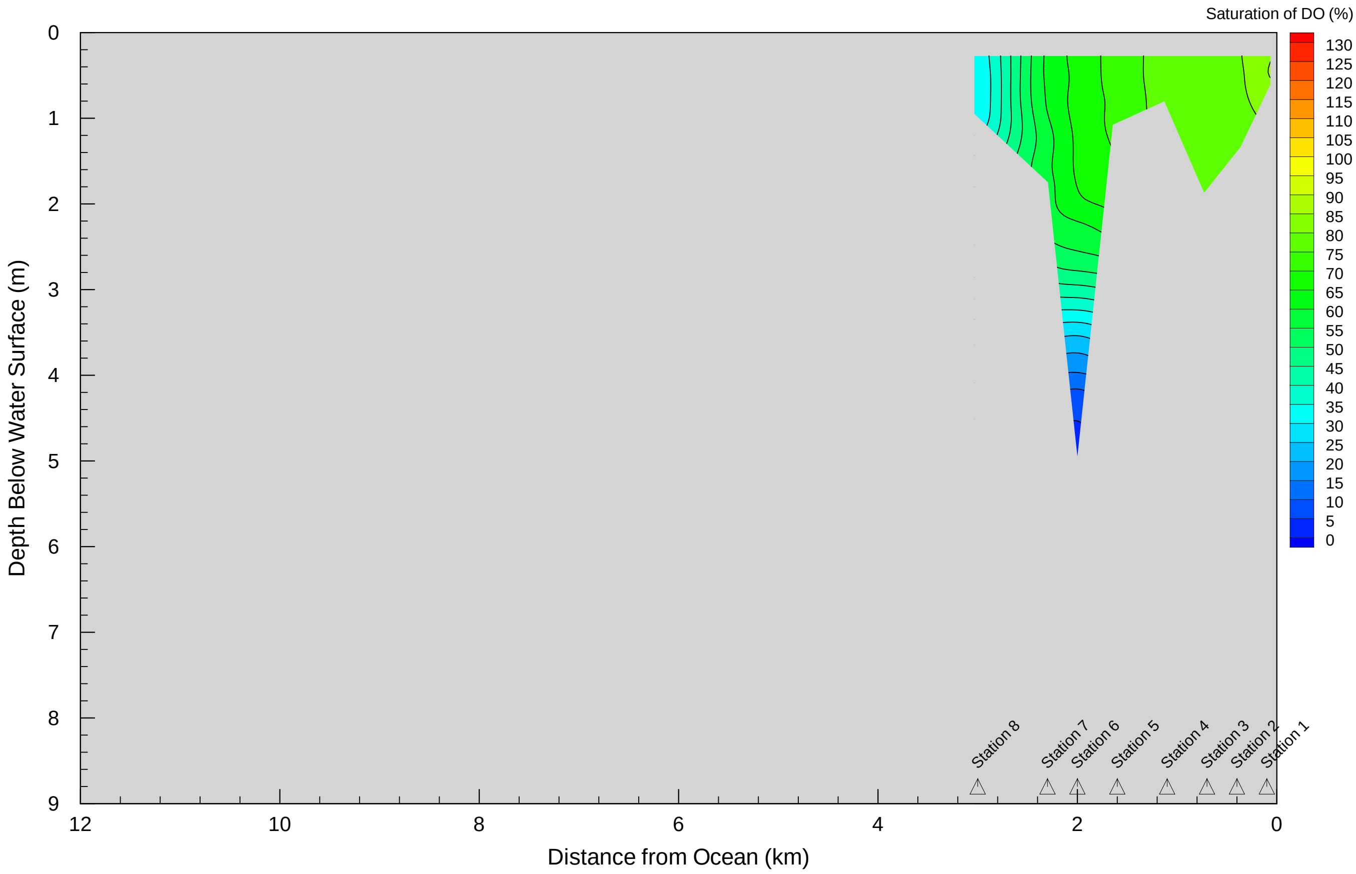
LONG CHANNEL SALINITY CONTOURS

26 OCTOBER 2003

MHL Report 1290

Figure D17

DRAWING 1290D017.BPS



NSW Department of Commerce

MANLY HYDRAULICS LABORATORY

BACK LAGOON

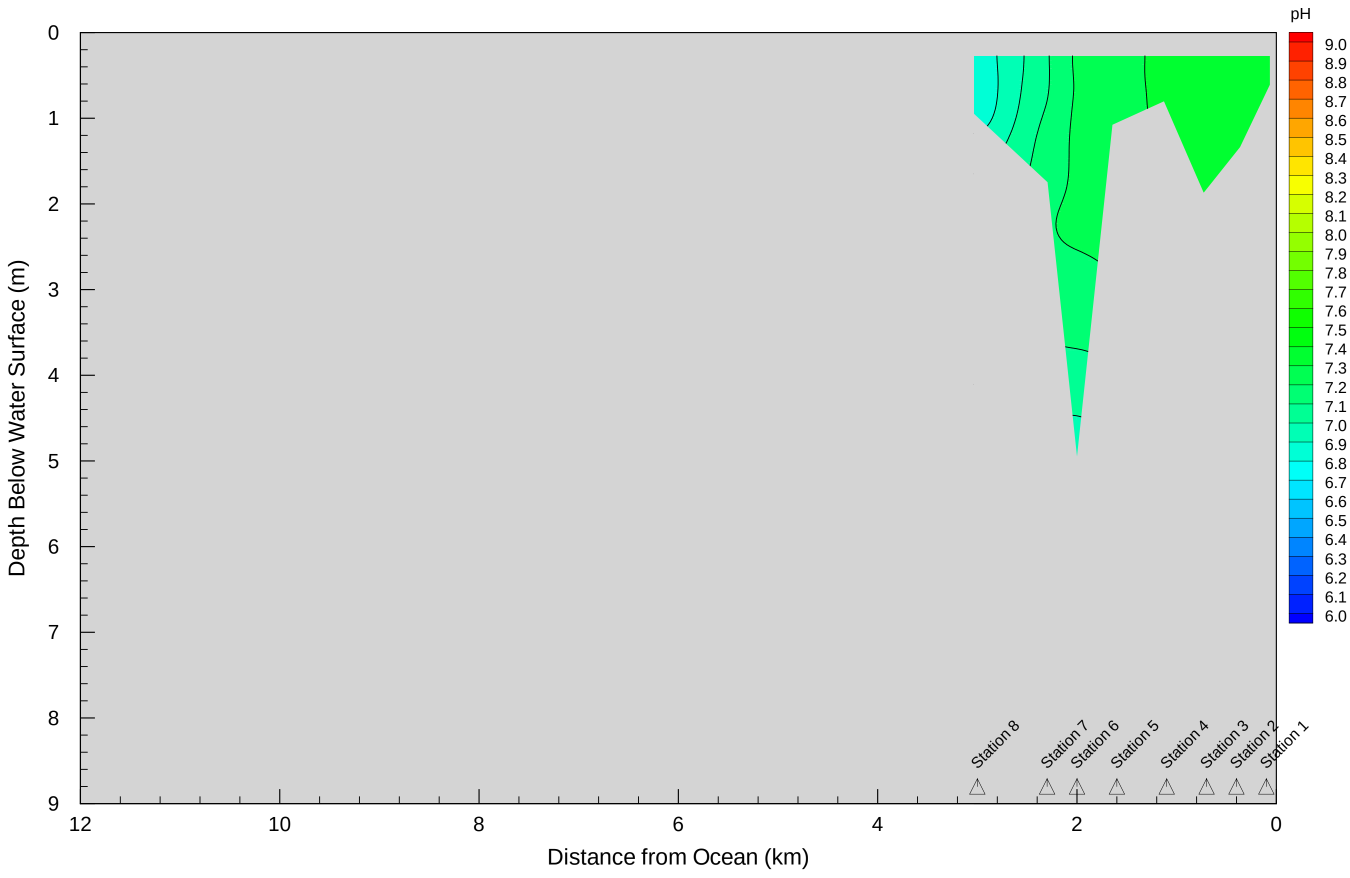
LONG CHANNEL % SATURATION OF DO CONTOURS

26 OCTOBER 2003

MHL Report 1290

Figure D18

DRAWING 1290D018.BPS



NSW Department of Commerce

MANLY HYDRAULICS LABORATORY

BACK LAGOON
LONG CHANNEL pH CONTOURS
26 OCTOBER 2003

MHL Report 1290

Figure D19

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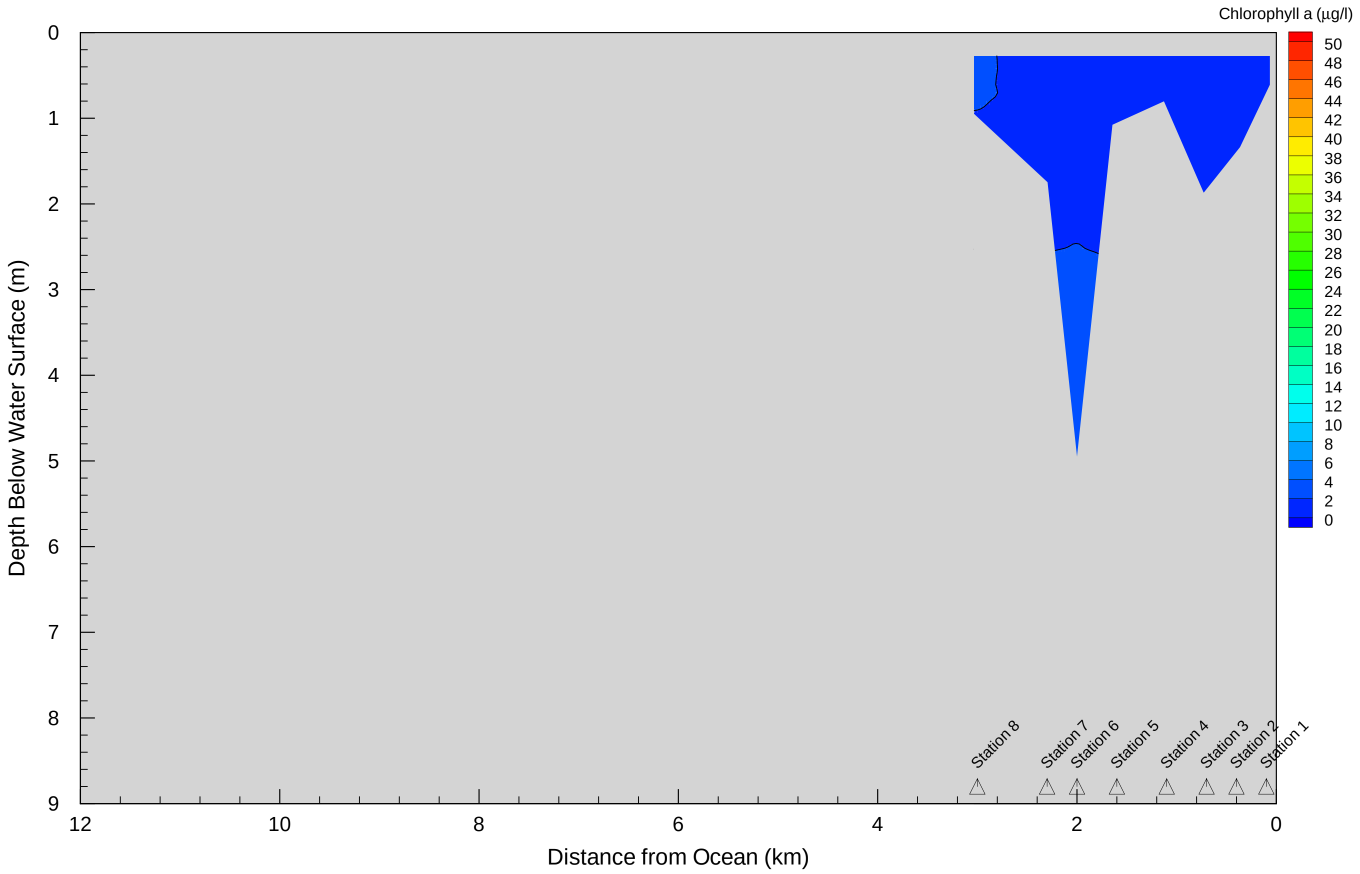

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BACK LAGOON

LONG CHANNEL CHLOROPHYLL-A CONTOURS

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Figure D20

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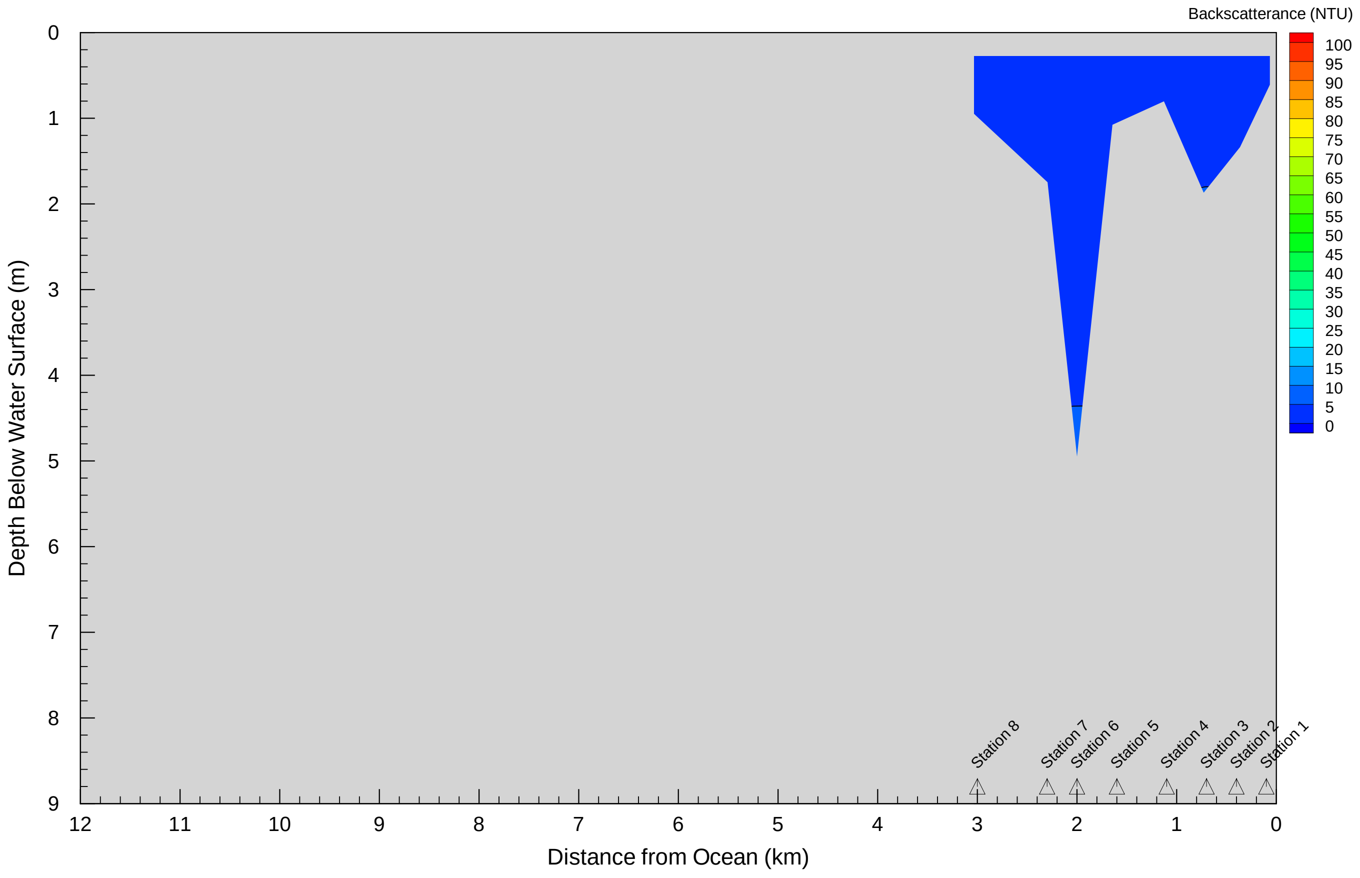

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MANLY HYDRAULICS LABORATORY

BACK LAGOON

LONG CHANNEL BACKSCATTERANCE CONTOURS

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Figure D21

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ESTUARY MANAGEMENT MANUAL - AN OVERVIEW

Introduction

The 130 estuaries along the coastline of New South Wales, form a rich and diverse tapestry of water bodies which vary in size from the long, mangrove-fringed river estuaries of the north coast through to the many lake estuaries distributed along the central and south coasts.

Collectively, the estuaries of New South Wales are of immense environmental, social and economic value.

Because of their attractiveness and value, estuaries are used for a wide variety of purposes, by different groups of people. Often, these uses are in conflict.

Sand and gravel extraction may degrade or eliminate seagrass beds which provide important nursery areas for young fish. Nutrient inputs from urban areas, from rural areas or from sewage treatment plants, can reduce water quality and foster the growth of undesirable aquatic plants. Poorly planned shoreside developments can destroy animal habitat, be an eyesore, reduce public access to estuarine shores, and cause pollution.

Estuaries are the end-point for the detrimental effects of many upstream catchment activities. Over the past 200 years, the inappropriate use, over-use and conflicts of use of our estuaries and their catchments, have left many of the estuaries of New South Wales in a degraded state. Further, estuaries and their immediate catchments are subject to ever-increasing pressures for additional areas to be developed, and for existing uses to be expanded.

The Need for a Coordinated Planning Approach

An estuary and its immediate catchment form a complex system of ecological, physical, chemical and social processes, which interact in a highly involved and, at times, unexpected fashion.

The diverse nature of estuarine lands, waters and processes, results in the division of estuary management between a number of government agencies. For example, the ownership and control of estuarine waterfront and submerged lands, is spread across a spectrum of private landholders, local councils, trustees, crown land and other New South Wales Government authorities.

A vital part of the estuary management process is community involvement and action.

This approach will result in the production of estuary management plans which are entirely consistent with the tenets of total catchment management and ecologically sustainable development.

The Estuary Management Program

The Policy

To foster better management of the estuaries of New South Wales, the government has formulated an Estuary Management Policy. The primary goal of this policy is to achieve the integrated, balanced, responsible and ecologically sustainable use of the state's estuaries. Specific objectives of the policy are:

protection and/or restoration/rehabilitation of estuarine habitats and ecosystems in the long-term, including maintenance in each estuary of the necessary hydraulic regime, and preparation and implementation of a balanced, long-term management plan for the sustainable use and/or ecological improvement of each estuary, in which all values and uses are considered, and which defines management strategies for:

- sustainable use of estuarine resources, including commercial and recreational uses, as appropriate;
- conservation and/or improvement of aquatic and other wildlife habitats;
- conservation of the aesthetic values of estuaries and wetlands;
- prevention of further estuary degradation; and
- repair of damage to the estuarine environment.

In essence, the policy sets the scene for cooperation between all levels of government, catchment management committees and estuary users, in the development and implementation of estuary management plans for each of the state's estuaries.

The Policy Framework

Total catchment management is the basis for natural resource management policy in New South Wales. Catchments are the natural planning units in which to optimise economic development, environmental protection and community wellbeing. As well as catchment management committees and trusts established under the Catchment Management Act 1989, total catchment management involves the development of statewide strategies for the sustainable use of soil, vegetation and water resources.

A major component of total catchment management is the Government's Rivers and Estuaries Policy which covers all aspects of the management of surface water bodies. The estuary management policy is a component of this policy, which in turn comes under the umbrella of total catchment management.

Estuary Management Plans

Estuary management plans should reflect the agreed position of all regulatory authorities and interested parties in relation to future nature conservation, rehabilitation and development of the estuary.

Estuary management plans will be prepared under the guidance of estuary management committees. Each committee will consist of representatives of local council(s), government agencies (as necessary), local community groups and representatives of catchment management committees and trusts.

The Manual

A draft Estuary Management Manual was released in 1992 to help develop and implement soundly based estuary management plans. The manual contains guidelines and principles for better estuary management to assist estuary management committees prepare and implement management plans. Readers should note that the manual does not provide ‘solutions’. Rather it presents a framework for making decisions that will result in better and sustainable estuary use.

The Estuary Management Manual is currently being revised to comply with the new NSW Government's Coastal Policy.

A copy of the draft Estuary Management Manual may be purchased for $20. Contact your Department of Land and Water Conservation Regional office in your area.

The Estuary Management Process

All eight steps of the estuary management process up to and including implementation and monitoring, are eligible for a 50% state government subsidy under the estuary management program administered by the Department of Land and Water Conservation.

Step 1 Form an estuary management committee

Step 2 Assemble existing data

- canvass community input; and
- discover and assemble relevant data.

Step 3 Carry out an estuary process study

- hydraulics: tidal, freshwater, flushing, salinity, water quality and sediment behaviour etc;
- biology: habitats, species, populations, endangered species etc;
- impacts: impact of human activities on hydraulics and biology; and
- (Note: an estuary process study may be compiled from existing data and community knowledge).

Step 4 Carry out an estuary management study

- community input recreational, social, economic, environmental etc;
- essential features: physical, chemical, ecological, economic, social and aesthetic;
- current uses: activities, land tenure and control, conflicts of use;
- conservation goals: preservation, key habitats;
- remedial goals: restoration of environmental quality;
- development: acceptable commercial and public works activities;
- management objectives: identification and assessment; and
- impacts: impact of proposed management measures.

Step 5 Prepare a draft estuary management plan

- management objectives;
- description of how the estuary will be managed;
- recommendations; and
- schedule of activities to implement recommendations.

Step 6 Review the draft estuary management plan

- public, council and government.

Step 7 Adopt and implement the estuary management plan as:

- council planning controls;
- government planning controls required;
- remedial works;
- monitoring programs;
- education programs;
- community services; and
- monitoring.

Step 8 Monitor and review

Form an Estuary Management Committee

The purpose of an estuary management committee is to direct and integrate the various steps of the estuary management process, to ensure that all issues of concern are addressed in a socially, environmentally and economically responsible fashion. In undertaking these tasks, the objectives of the estuary management committee should be consistent with those of the estuary management policy itself.

The composition of an estuary management committee will depend upon the specific issues and problems in the subject estuary. In order to be effective, the committee must include representatives of local community groups, relevant authorities, the local catchment management committee, council staff and councilors and users of the estuary.

Assemble Existing Data

Often, there is a considerable body of data relevant to estuarine processes and management, generally in the form of maps and reports that are available from various government agencies.

One of the first tasks of the estuary management committee should be to arrange for the discovery and assembly of these data. This will provide a basis for assessing the type and scope of any additional data which may need to be collected in future studies and programs. The committee may also commission any necessary studies to review these data, and determine the need for additional investigations.

Carry Out an Estuary Process Study

The purpose of an estuary process study is to define the 'baseline' conditions of the various estuary processes, and the interaction between these processes. Before management options for an estuary can be meaningfully considered, it will generally be necessary to undertake an estuary process study.

In designing an estuary process study, it is important that the interactions between physical, chemical and biological processes occurring in the estuary itself, and between estuarine, ocean and upstream catchment processes, be recognised at the outset, (eg the significance of ocean flushing and the action of surface run-off in delivering freshwater and its dissolved and suspended constituents, to the estuary).

Carry Out an Estuary Management Study

An estuary process study provides essential background information on estuarine processes and their interactions. An estuary management study uses this information, together with additional studies, to define management objectives, options and impacts. To effectively manage all uses of an estuary, it may be necessary to have regard for specific uses, such as oyster growing, tourism, etc. User or industry-based organisations are often available to assist with such studies, eg oyster farmers' associations and the New South Wales Tourism Commission. The estuary management committee should be aware of such organisations and seek their assistance and advice, when appropriate.

An estuary management study will seek to:

- identify the significance of the estuary in terms of broader coastal and catchment planning issues;
- identify ‘essential features’ of the estuary, be they physical, chemical, biological, aesthetic, social or economic;
- document current uses and conflicts of use within the estuary;
- identify possible future land and waterway uses and their impact on ‘essential features’;
- assess the need for nature conservation and remedial measures;
- identify critical issues that need to be addressed;
- identify and assess management objectives;
- assess planning controls, works and other strategies to achieve these objectives; and
- broadly assess the management of current and future ‘estuarine assets’.

Prepare a Draft Estuary Management Plan

An estuary management plan consists of a scheduled sequence of recommended activities that need to be undertaken to achieve the estuary management objectives.

Completion of the estuary management process and management studies will provide a sound basis for the formulation of a management plan, which takes into account the considered views of all parties on the estuary management committee. The plan may require trade-offs and compensatory balances if differing viewpoints are to be accommodated.

Activities incorporated in a management plan may relate to nature conservation, rehabilitation, development, education and other matters. Some management measures are ‘one-off’ in nature, eg remedial works and the adoption of a local environmental plan. Other measures are ongoing, such as improvement in land management practices, community education programs, and monitoring surveys. Yet other measures will need to be phased in over time, eg changes in land use that can only be realised on lease expiry or sale of land.

Review Draft Estuary Management Plan

Estuary management plans will be subject to public display and review. This will provide all interested or affected parties with the opportunity:

- to assess what is proposed for the estuary, the means and implications of proposed controls etc;
- to register objections; and
- to make constructive comments in relation to objectives, issues, solutions and options, and the needs of ‘interested parties’.

The estuary management committee will take these comments into account when finalising the estuary management plan.

After public display and any necessary amendments, an estuary management plan must be formally adopted by local council(s) before it is implemented.

Adopt and Implement the Estuary Management Plan

The estuary management committee should oversee the implementation of the estuary management plan.

The following methods can be used, either separately or collectively, to implement the recommendations of an estuary management plan:

- local environmental plans and development control plans introduced by local government for the control of new development (under the Environmental Planning and Assessment Act);
- environmental planning policies introduced by the state government, such as State Environmental Planning Policy 14 (Coastal Wetlands) and regional environmental plans;
- designation of aquatic reserves and protected land;
- voluntary conservation agreements;
- construction of physical restoration, protection or improvement works by local government, state government, the private sector or community groups, either individually or collectively;
- controls by state government agencies; and
- other measures, such as community education programs.

Monitor and Review

Having adopted a management plan and commenced its implementation, it will be necessary to monitor outcomes to ensure that management activities and controls are having the desired effects on estuarine habitat and amenity.

Monitoring programs will generally be of two types:

- ongoing ‘baseline monitoring’ to measure the general ‘health’ of the estuary; and
- ‘event monitoring’ to record the impact of some development or natural event.

In addition to collecting monitoring data, it is also necessary to review these data, to assess the success, or otherwise, of implementation activities. In the light of these findings, it may be necessary to amend the estuary management plan, even to the extent of changing its objectives.

An estuary management plan is not a static instrument. It needs to be reviewed on a regular basis, and updated where necessary to cater for the changing needs and desires of society.

Government Financial Assistance

The New South Wales Government will facilitate the formulation and implementation of estuary management plans, through the provision of both technical and financial assistance.

For investigations and activities associated with the development and implementation of estuary management plans, a 50% subsidy is available under the Government's estuary management program, which is administered by the Department of Land and Water Conservation. Activities eligible for subsidy, include data collection and review, surveys, the undertaking of estuary process and estuary management studies, the preparation, display and review of estuary management plans, and the undertaking of management activities recommended in the plan, including works, public awareness programs, monitoring activities, etc.

Estuary management committees are encouraged to seek grant monies from other sources (eg Federal Government programs) and to obtain money from within the community by special rate levies, etc.

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D P W S

NSW DEPARTMENT OF PUBLIC WORKS AND SERVICES

Manly Hydraulics Laboratory (MHL) provides specialist services in the area of water, coastal and environmental solutions.

- MHL is a business unit within the Department of Public Works and Services
- MHL has a quality system certified to AS/NZS ISO 9001 : 1994

Areas of expertise include:

- investigation of oceanographic, coastal, estuarine and riverine processes
- environmental and water quality studies, data aquisition and field surveys
- design and testing of water engineering structures and equipment
- development and operation of physical and numerical models

MHL also provides Internet services for customers such as:

- Coastal Environment Centre
- Lake Ainsworth Management Study
- Wagonga Inlet Management Study
- Jimmys Beach Management Study
- Yamba Coastline Management Plan
- 27th International Conference on Coastal Engineering

Some images of the physical model facilities are also available:

- Irrigation Flow Testing.
- A Model of Warragamba Dam.

- 2 Dimensional Wave Basin.
- A Road Kerb Inlet Model.

Tidal Prediction Charts for NSW compiled by MHL are now available in two publications available in most seaside newsagents and provide an invaluable aid in recreational activities such as fishing, boating, sailing, sailboarding, diving and waterskiing and industries such as salvage and coastal engineering.

MHL real-time environmental data page.

Site location and facilities	Site redevelopment	Remote Sensing	Investigations	Environmental and water quality studies	Field surveys	Data acquisition

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Types of Investigations at Manly Hydraulics Laboratory

Marine and Coastal Studies

- Coastal and marine processes.
- Beach erosion, nourishment and management.
- Wave climates.
- Storm surges.
- Harbours, ports, marinas and breakwaters.
- Sediment transport.

Estuarine Studies

- Estuarine management.
- Total catchment management.
- Environmental monitoring and assessments.
- Water quality.
- Wetlands.
- Waterway facilities (wharves jetties and boat ramps).
- Saline intrusion and currents.
- Tides and floods.
- Climatic change and greenhouse effects.
- Dredging.

Riverine Studies

- Dams and spillways.
- Hydraulic design of culvets and bridges.
- Flood studies, modelling and flood plain management.
- Water quality and pollution studies.

Water and Hydraulic Studies

- Storm water drainage and detention systems.
- Inlet and outlet works.
- Fountain flow design.
- Pipe flow.
- Sewage Investigations.


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