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Report on a Hydrographic Survey Trilleachan-Mhor, Loch Seaforth, Harris (NB 20840 07489) 18th June to 3rd July 2005

Client: Fjord Seafood in 2005, amended report for Lighthouse Caledonia Ltd. in 2008

Report on the deployment of current meter at Trilleachan-Mhor, Loch Seaforth, Harris, from 18th June to 3rd July 2005.

1. Introduction

This document reports on the deployment of a single Nortek 500kHz Acoustic Doppler Current Profiler (ADCP) and the measurement of water currents at Trilleachan-Mhor, Loch Seaforth, Harris, between 18th June to 3rd July 2005. An automatic weather station was also deployed close to the site to record wind data concurrent with the measurement of currents.

Mean water depth at the location is 34.88m. The positional co-ordinates of the Nortek ADCP and weather station were taken using a Garmin e-Trex, GPS meter and are given in Table 1b. The positions of the ADCP and weather station are also indicated in the map section in Figure 1.

This report illustrates abstracts from the data collected at three depths, namely 28m, 25m and 2m from the seabed in order to fulfil the hydrographic data requirements of SEPA for fish farm sites.

This report attempts to offer some guidance to the client on the basis of the limited nature of the data gathered. No firmer conclusions can be drawn without a wider study of the climatic, hydrographic and topographical features of the site area and the approaches to it.

Figure 1: Map of area

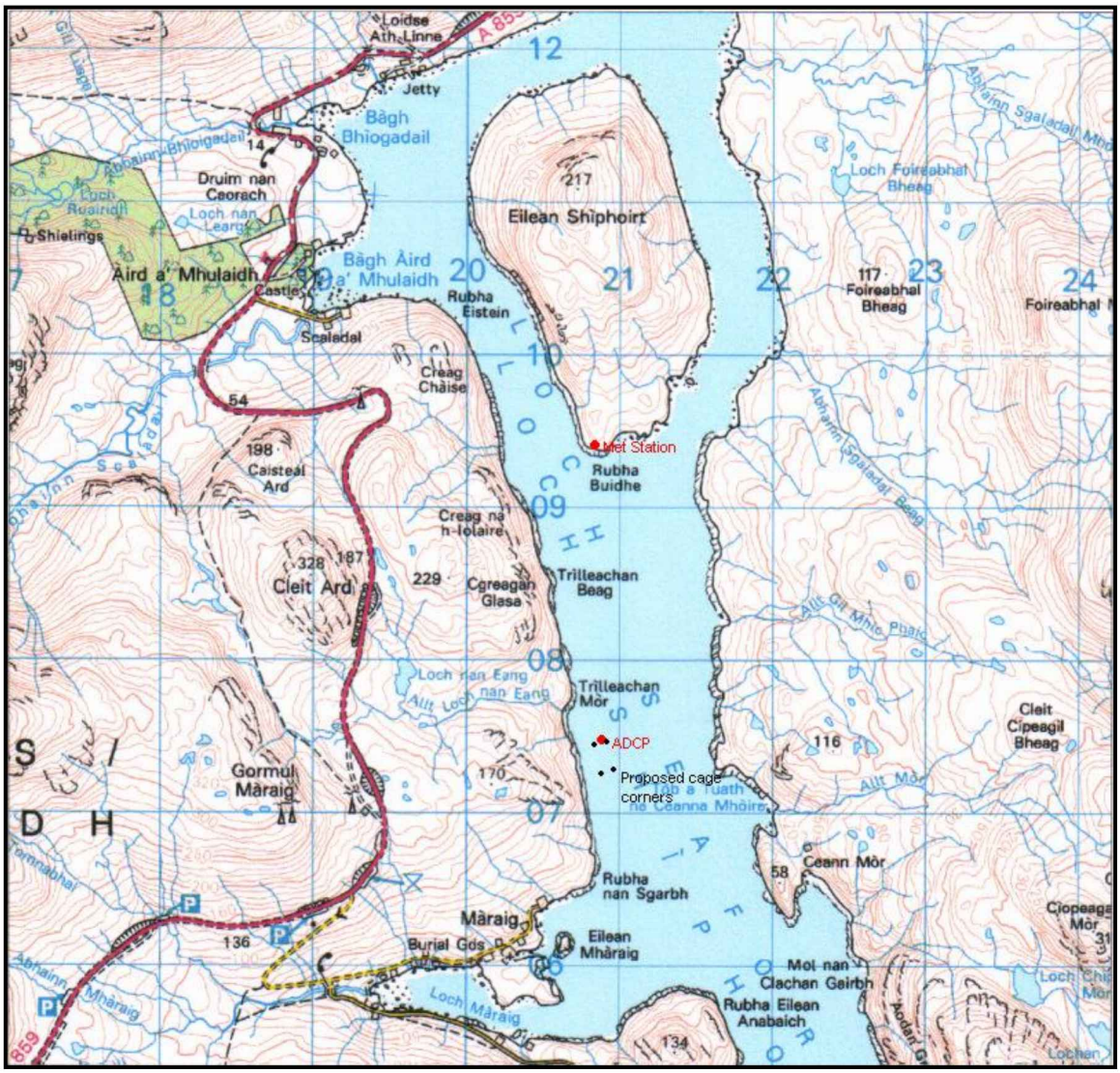

Figure 2: Marine chart map

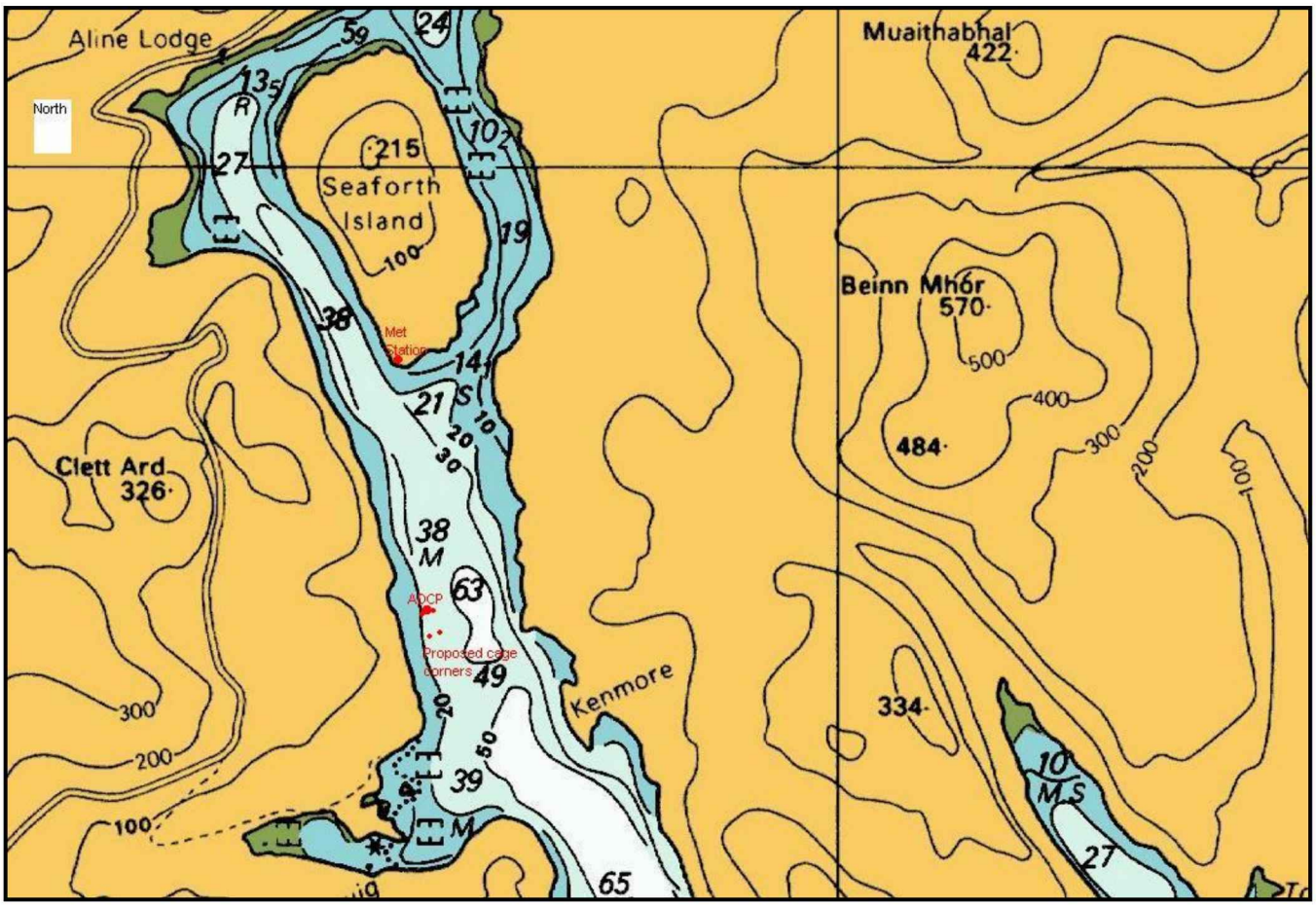

Figure 3: Deployment of Nortek ADCP showing arrangement of data collection cells

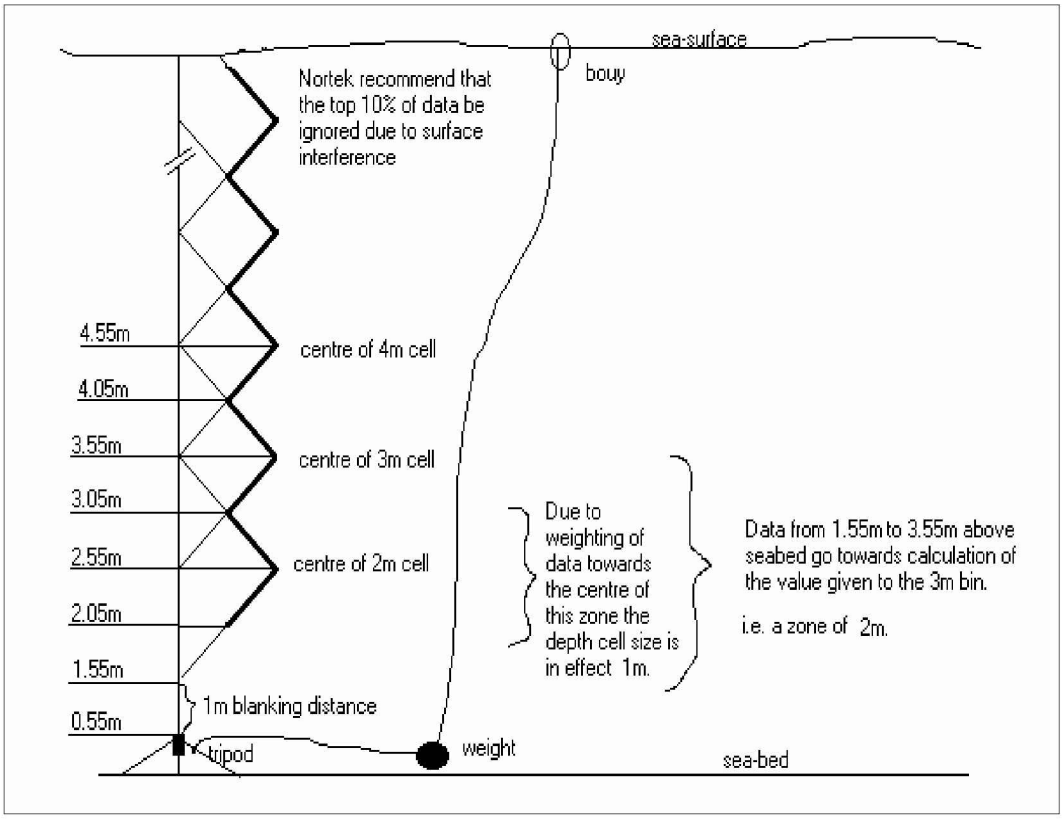

Table 1a: Cage block co-ordinates derived theoretically from mapping package

Cage Corner	Depth m to Chart Datum	GPS	
		NGR	WGS84
NW	24.4	NB 20804 07458	57°58.107 6° 43.388
NE	34.1	NB 20892 07480	57°58.122 6° 43.300
SW	22.1	NB 20857 07239	57°57.991 6° 43.318
SE	37	NB 20946 07262	57°58.007 6° 43.230

Table 1b: Monitoring equipment co-ordinates

Monitoring Equipment	Predicted tidal height, m	Depth m to Chart Datum		GPS		No. of satellites	Accuracy of fix
		Sounding	CD	NGR	WGS84		
ADCP	35.6m	34m	1.6m	NB 20840 07489	57° 58.12 6° 43.35	4	<5m
Weather Station	n/a	n/a	n/a	NB 20825 09393	57° 59.15 6° 43.50	4	<5m

2. Methods

The ADCP, with tripod, total height 550mm, was deployed on the seabed in the vicinity of the proposed cage array at Trilleachan-Mhor. It was secured to a bottom anchor and its position marked by a buoy, as shown in Figure 3. The Nortek ADCP is capable of current measurement at multiple depths as set by the operator. In this case, the meter was set to record data at 1m intervals from 2m above the seabed to the sea surface. The lowest recorded sea depth at the site of the meter was 32.58m (see tidal range, Figure 11). The meter was left in place, recording water depth and current speed and direction at 20-minute intervals on a continuous basis, between midnight on 18th June 2005 and midnight on 3rd July 2005 in order to fulfil the SEPA requirement for such measurements over a 15-day period (i.e. half a lunar cycle).

The proposed cage group at Trilleachan-Mhor comprises of 10 cages, with the current meter being 133m to the north-north-west of the centre of the cage group. The cage corner positions have been derived theoretically from a mapping program to chart datum. GPS positions were converted using the software Grid Inquest, current and wind direction have been corrected to Grid North by subtracting 4 ^{o} using up to date information at the time of the initial writing of the report in 2005. The tidal correction for the deployment of current meter has been taken from the information given from the software package; Total Tide, using East Loch Tarbert as the closest secondary port.

A recording anemometer was also deployed near to the ADCP site for the same period, to measure wind speed and direction. The anemometer recorded wind speed and direction every three hours throughout the period of the ADCP deployment.

3. Results

The data reported are abstracted from the complete dataset collected, for the specific depths 28m, 25m and 2m from the seabed. The raw dataset has also been collated on a disc, accompanying this report.

The following current meter and associated data are presented in graphical and tabular form in this report: -

Figure 4.1-4.3.	Scatter plots of current meter observations at 28m, 25m and 2m from the seabed.
Figure 5.1-5.3.	Cumulative vector plots of current meter observations at 28m, 25m and 2m from the seabed.
Figure 6.1-6.3.	Time series plots of current speed measurements at 28m, 25m and 2m from the seabed.
Figure 7.1-7.3.	Rolling 3-hour average of current speed measurements at 28m, 25m and 2m from seabed.

Figure 8.1-8.3.	Percentage of current readings by compass direction at 28m, 25m and 2m from the seabed.
Figure 9.1-9.3.	Average current speed by compass direction at 28m, 25m and 2m from the seabed.
Figure 10.1-10.3.	Percentage frequency distribution of current speed at 28m, 25m and 2m from seabed.
Figure 11.	Tidal height as water depth to seabed.
Figure 12.	Depth of data recording cells from water surface, corresponding to 28m, 25m and 2m from the seabed.
Figure 13.	Wind speed and direction.
Figure 14.	Wind direction, frequency % by 10° intervals.
Figure 15.1–15.3.	Time series of current direction and water depth at 28m, 25m and 2m from the seabed.
Figure 16.1-16.3.	Time series of current direction and water depth at 28m, 25m and 2m from the seabed.
Figure 17.1-17.3.	Percentile against current speed at 28m, 25m and 2m from the seabed.
Figure 18.	Heading, pitch and roll.
Table 2.	Data analysis
Table 3.	Equipment specifications.

The data gathered at the recording anemometer and from the Nortek ADCP, at the three depths selected, indicate the following: -

- Average wind speed throughout the 15-day recording period was 10.16ms^{-1}. Initially wind speeds were generally higher than the average speed, reaching a maximum of 20.83ms^{-1} (Gale, Beaufort Force 8). However wind speeds dropped considerably over the next 8 days and there was a period from 27th to 30th June, when the average wind speed was below 10ms^{-1} for 3 consecutive days, thus fulfilling SEPA's requirements of 3 consecutive days with mean wind speeds less than 10ms^{-1}.

- Wind directions were from mainly from the southerly quarter; see Figure14.

- Mean water depth at the ADCP site was 34.88m over the recording period.

- The maximum spring tide depth range at the ADCP site was 4.4m, between 37.07m (high water) and 32.67m (low water) (23rd/24th), and 36.98m (high

water) and 32.58m (low water) (24th/25th June). The minimum neap tide range (30th June) was 1.9m, between 35.73m (high water) and 33.83m (low water). (Figure 11).

- Mean current speeds during the ADCP deployment were as follows

	Mean speed cms^{-1}
28m from seabed	6.86
25m from seabed	6.64
2m from seabed (deepest)	5.22

- Illustrated by figures 6.1-6.3, 7.1-7.3, 10.1-10.3 and 17.1-17.3 average current speeds are all between $5cms^{-1}$ and $10cms^{-1}$ i.e. moderately flushed. Calculated mean speed indicates that current speeds increase from the seabed to the surface, through the water column.

- Currents were below $3cms^{-1}$ at 3m above the seabed for approximately 17% of the recording period, as shown by figures 10.1 – 10.3 and figures 17.1 – 17.3.

- Current speeds were generally greater than the average speeds for the duration of the peak flood flow, (see figures 7.1 – 7.3 and 16.1-16.3).

- Figure 17.2 – 17.3 indicate that for the bottom and mid depths the percentage of current speeds below $3cms^{-1}$ is 16.56%, thus slightly quiescent.

- The cumulative vector plots Figures 5.1-5.2 indicates residual current direction is in a southerly direction at 28m and 25m above the seabed. At 2m above the seabed (Figure 5.3) there is a lower residual current and it is in a north westerly direction.

- Figure 4.1–4.3 scatterplots illustrate a tidal axis corresponding to that illustrated by the oscillations in the cumulative vector plots (figures 5.1 – 5.3).

- Figures 8.1 – 8.2 indicate the main tidal direction is in a southerly direction with a weaker northerly reciprocal current. At 2m above the seabed, the frequency of current directions is fairly uniform, slightly weaker currents are seen to be in the SW quarter.

- Figures 9.1 – 9.3 read alongside figures 8.1 – 8.3 confirm that the most frequent current directions are also the strongest currents.

- Figure 11 read alongside figure 15.1 to 15.2 indicates that currents tend to flow in a southerly direction with an ebb tide and to the north during the flood tide.

Figure 4.1-4.3: Scatterplots of current vectors, cms^{-1} at selected depths from seabed (m).

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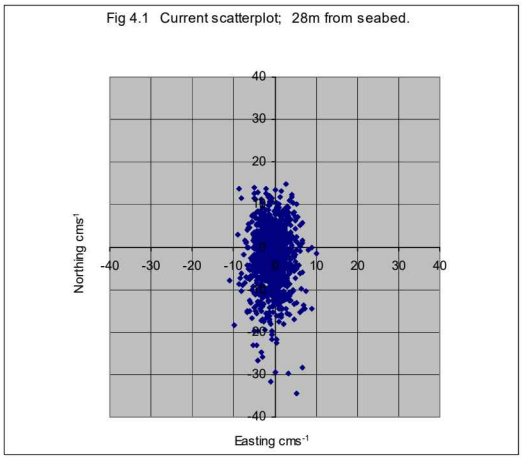
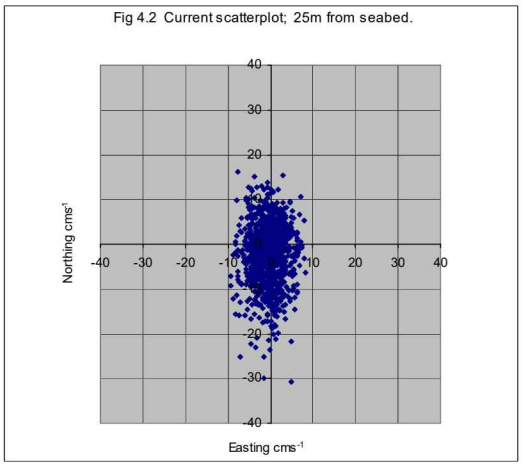
From 00:00 18.06.05 to 00:00 03.07.05 (GMT); 15 days.





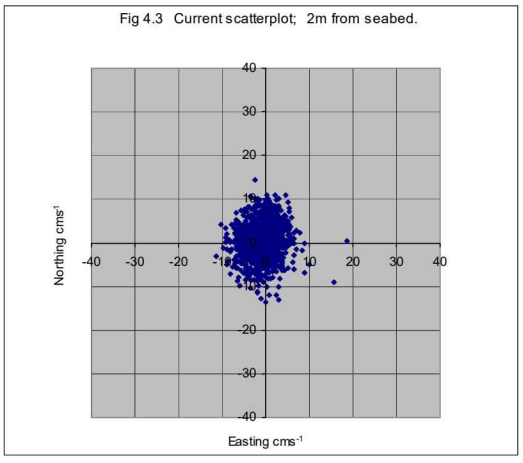
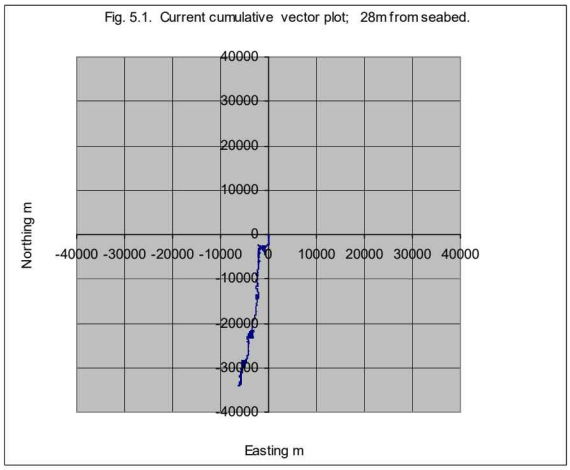
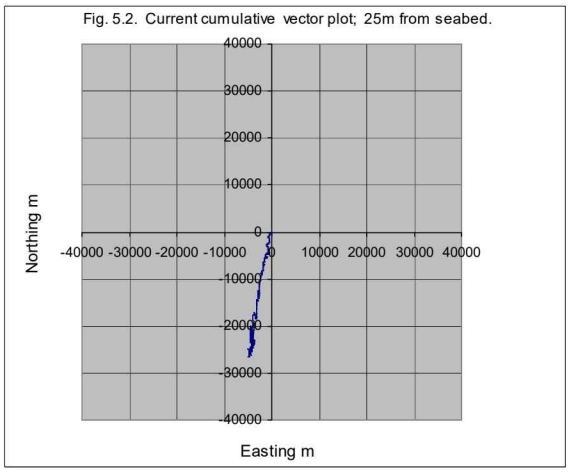


Figure 5.1-5.3: Current cumulative vector plots (m) at selected depths from seabed (m).

Trilleachan-Mhor O/S Grid Ref NB 20840 07489
From 00:00 18.06.05 to 00:00 03.07.05 (GMT); 15 days.





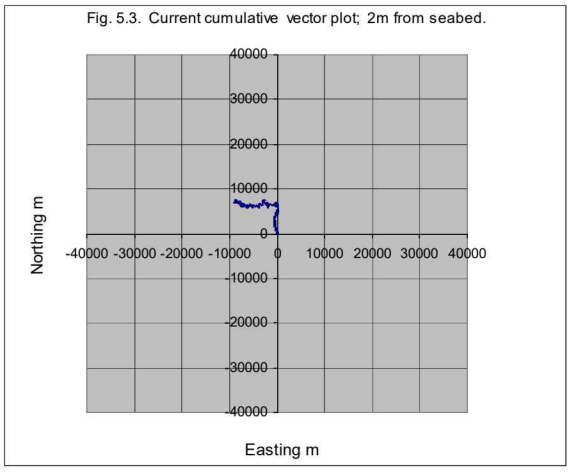
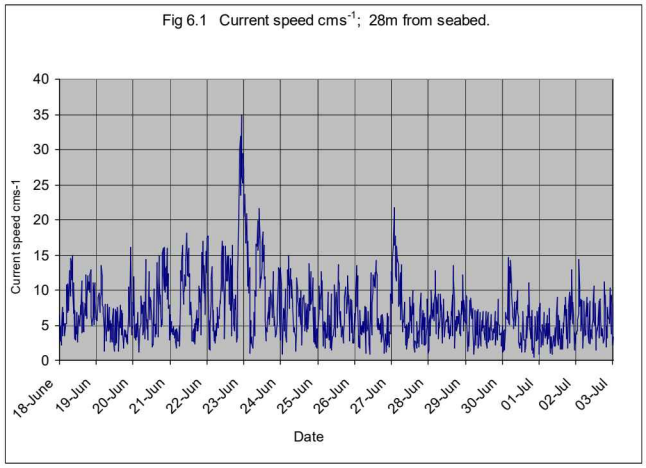
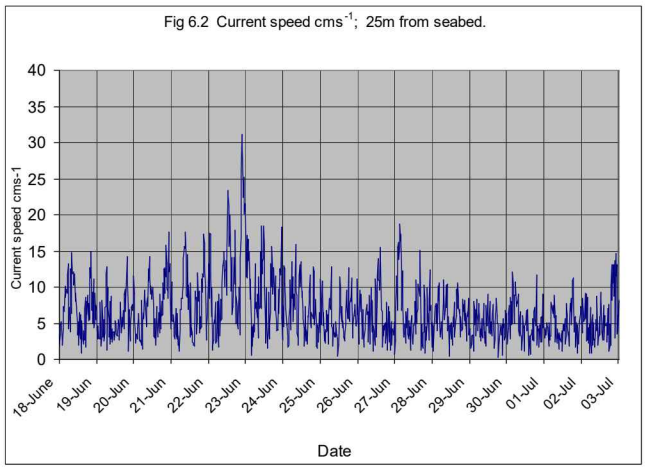


Figure 6.1-6.3: Current speed (cms^{-1}) at selected depths from seabed (m).

Trilleachan-Mhor O/S Grid Ref NB 20840 07489
From 00:00 18.06.05 to 00:00 03.07.05 (GMT); 15 days.





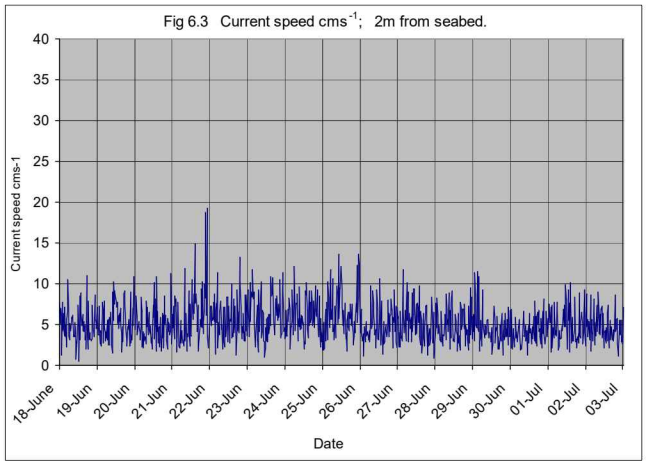
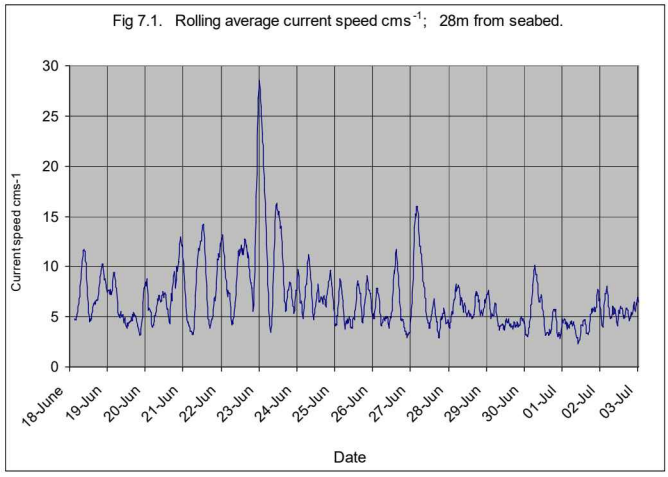
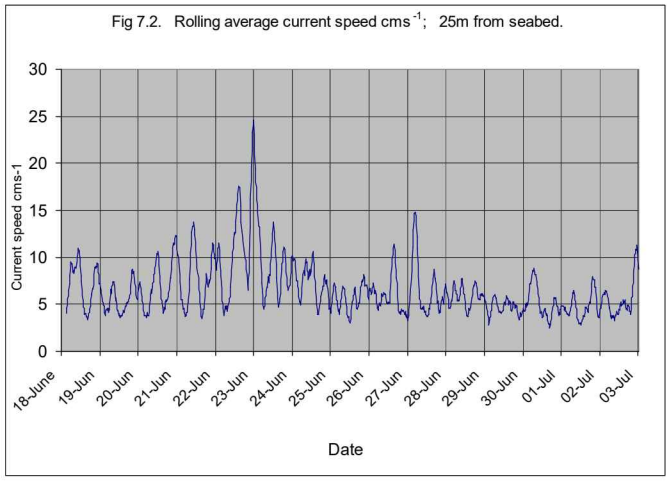


Figure 7.1-7.3: Rolling average current speed (cms^{-1}) at selected depths from seabed (m).

Trilleachan-Mhor O/S Grid Ref NB 20840 07489
From 00:00 18.06.05 to 00:00 03.07.05 (GMT); 15 days.





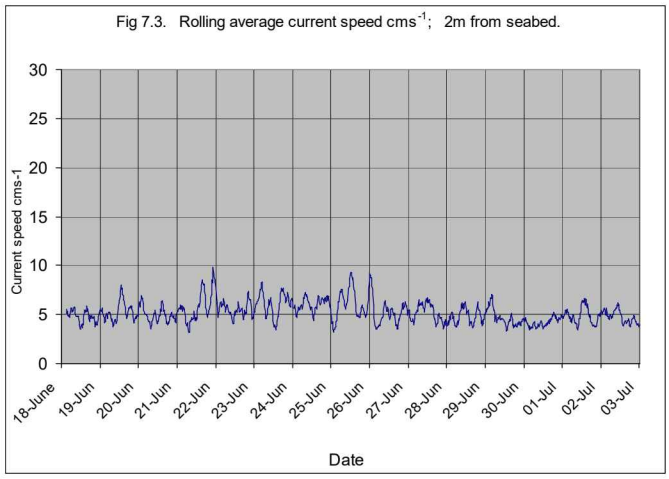
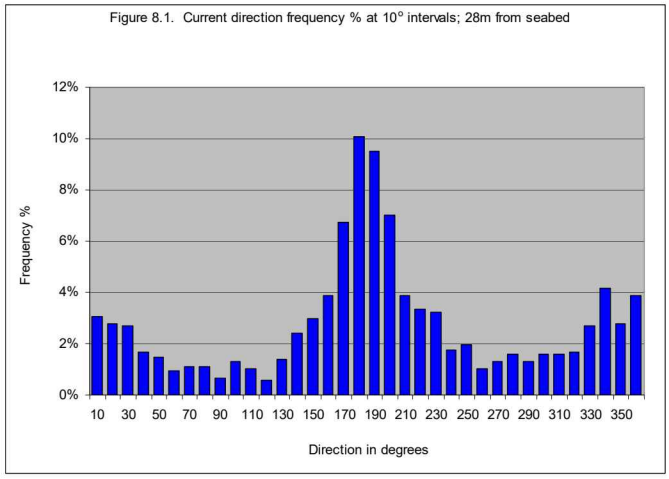
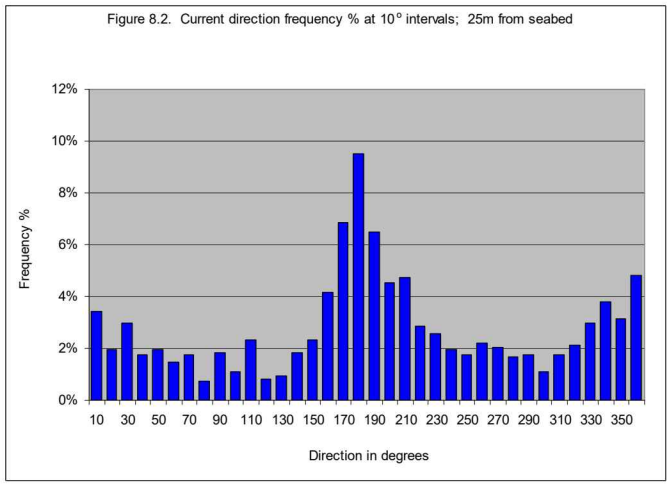


Figure 8.1-8.3: Current direction frequency % in direction bins at 10° intervals at selected depths from seabed (m).

Trilleachan-Mhor O/S Grid Ref NB 20840 07489
From 00:00 18.06.05 to 00:00 03.07.05 (GMT); 15 days.





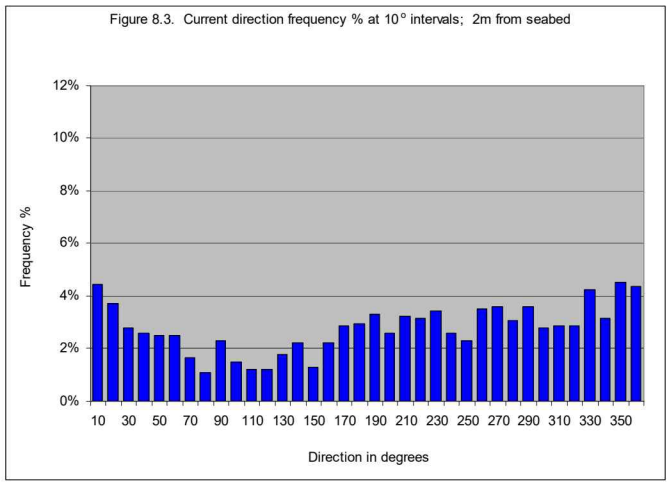
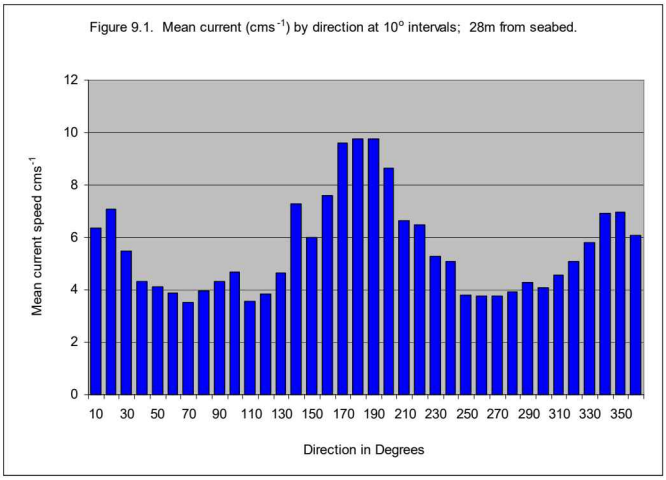
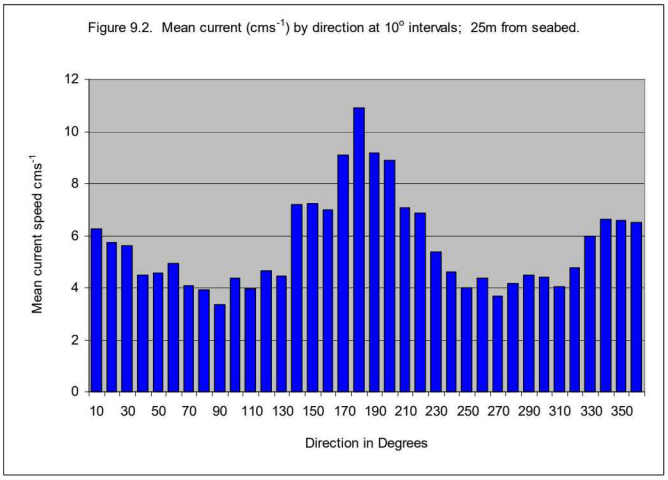


Figure 9.1-9.3: Mean current speed (cms^{-1}) in direction bins at 10^{o} intervals at selected depths from seabed (m).

Trilleachan-Mhor O/S Grid Ref NB 20840 07489
From 00:00 18.06.05 to 00:00 03.07.05 (GMT); 15 days.





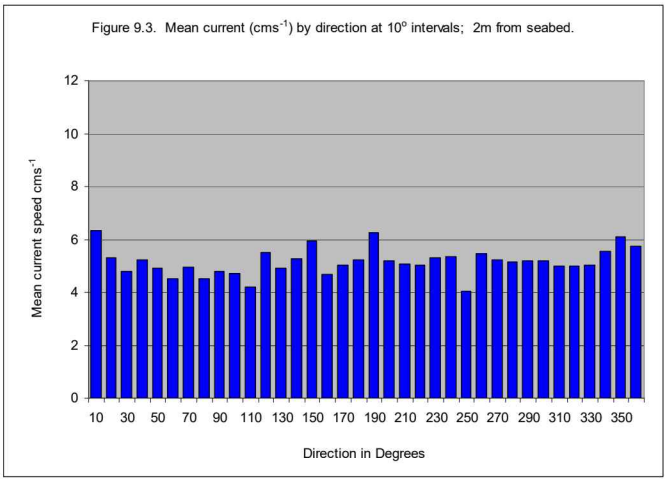
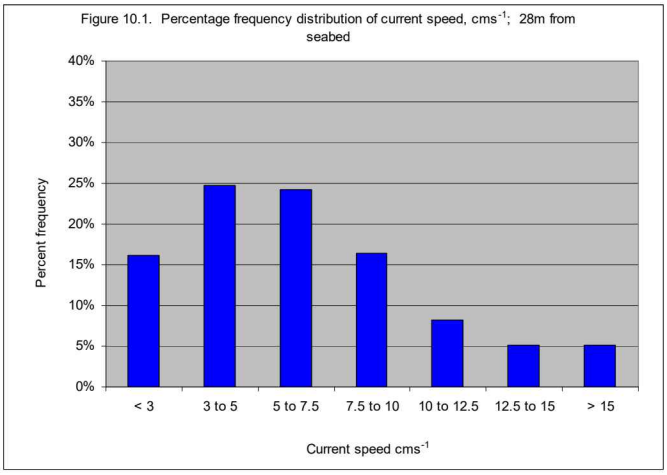
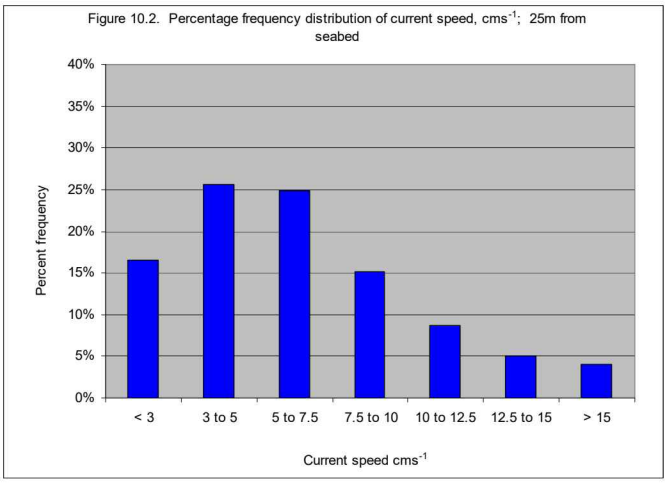


Figure 10.1-10.3: Percentage frequency distribution of current speed, cms^{-1} at selected depths from seabed (m).

Trilleachan-Mhor O/S Grid Ref NB 20840 07489
From 00:00 18.06.05 to 00:00 03.07.05 (GMT); 15 days.





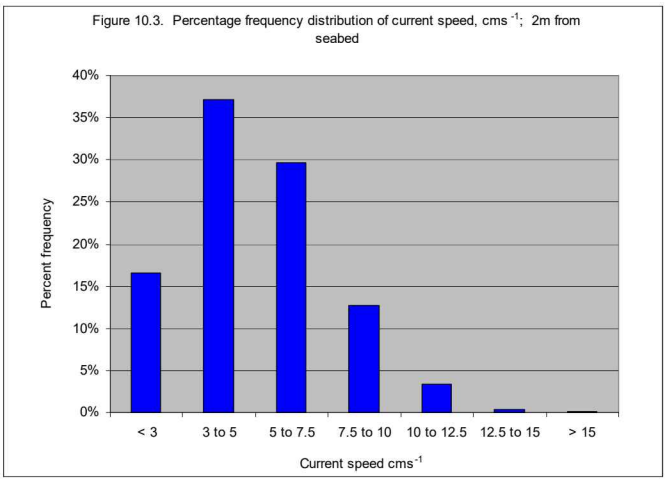


Figure 11: Tidal height as water depth to seabed, m at ADP site.

Trilleachan-Mhor O/S Grid Ref NB 20840 07489
From 00:00 18.06.05 to 00:00 03.07.05 (GMT); 15 days.

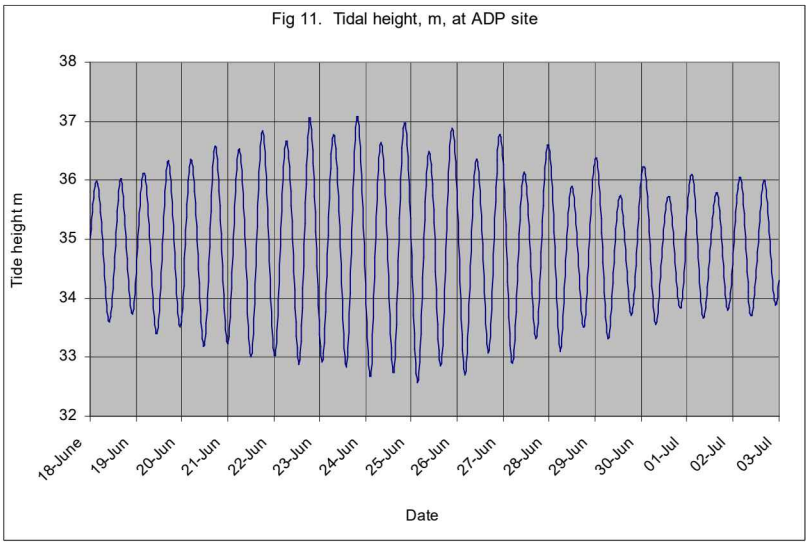


Figure 12: Variation in depth of ADP cells from water surface, m, with tidal flux.

Trilleachan-Mhor O/S Grid Ref NB 20840 07489
From 00:00 18.06.05 to 00:00 03.07.05 (GMT); 15 days.

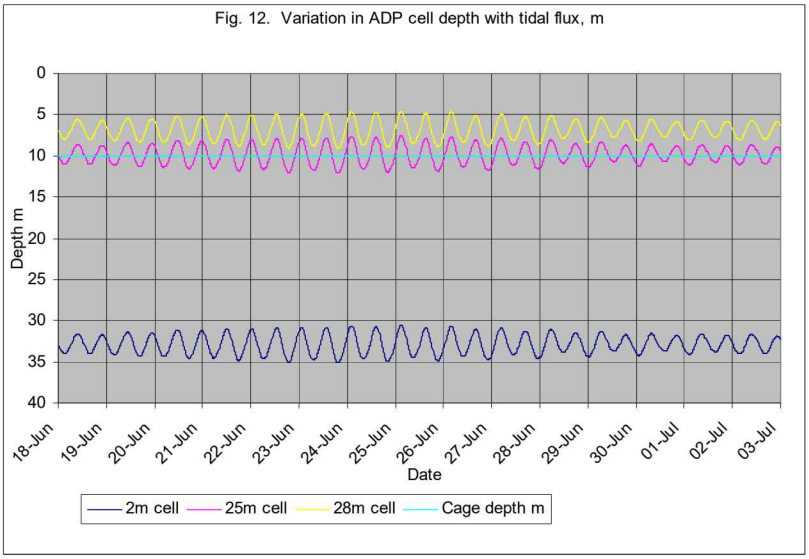


Figure 13: Wind speed data, ms^{-1} and direction, from recording anemometer.

Trilleachan-Mhor O/S Grid Ref NB 20840 07489
From 00:00 18.06.05 to 00:00 03.07.05 (GMT); 15 days.

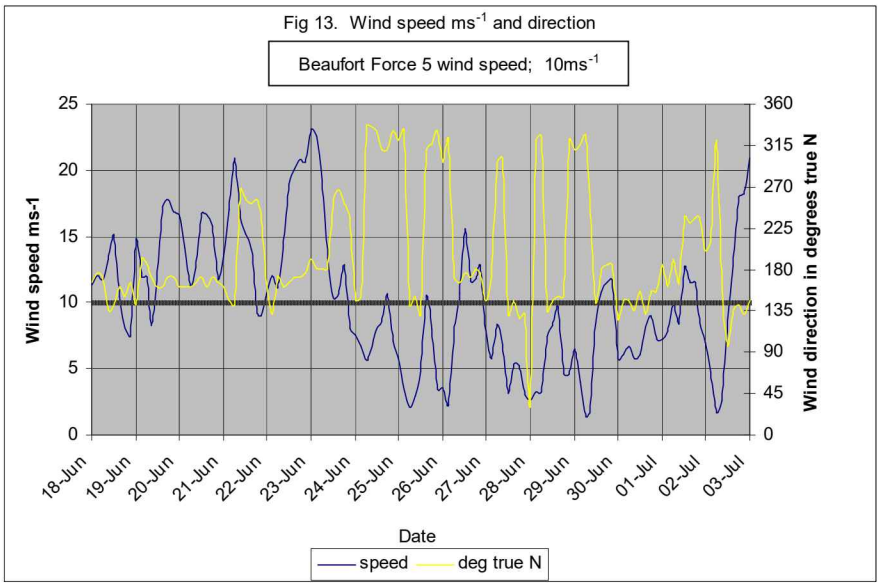


Figure 14: Wind direction, frequency %.

Trilleachan-Mhor O/S Grid Ref NB 20840 07489
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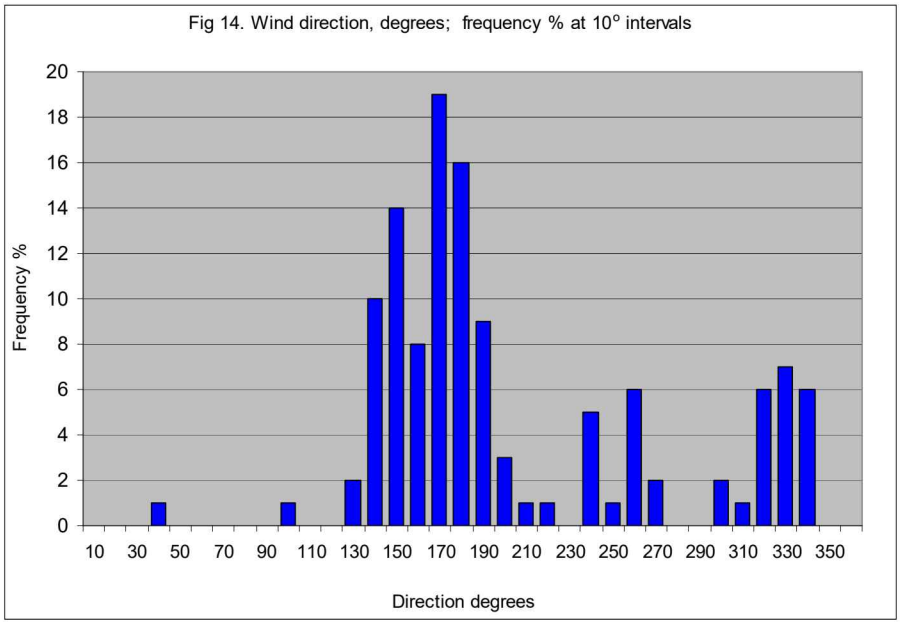
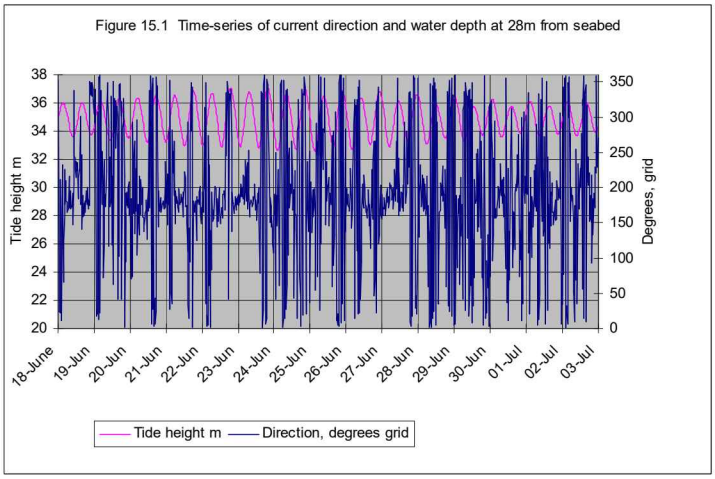
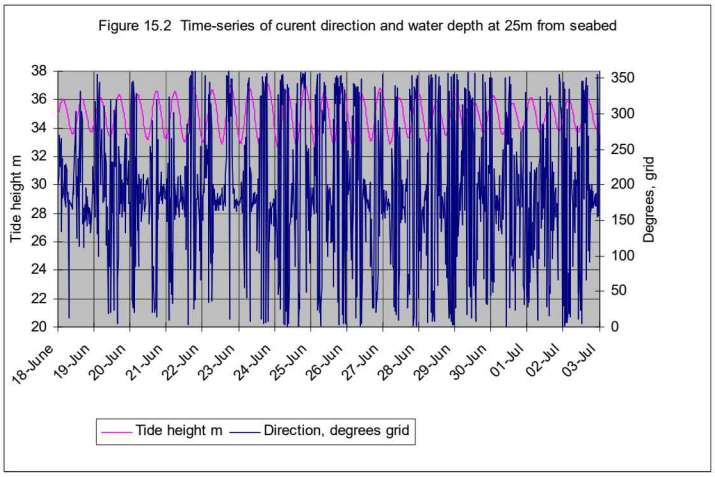


Figure 15.1-15.3: Time series graphs of current direction and tidal height at selected depths from seabed

Trilleachan-Mhor O/S Grid Ref NB 20840 07489
From 00:00 18.06.05 to 00:00 03.07.05 (GMT); 15 days.





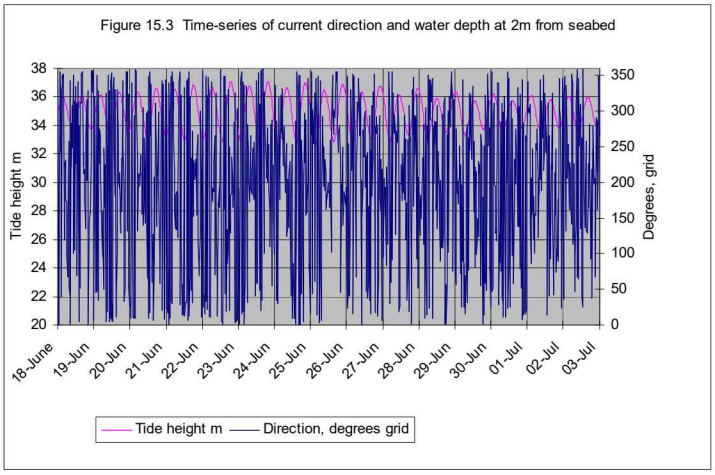
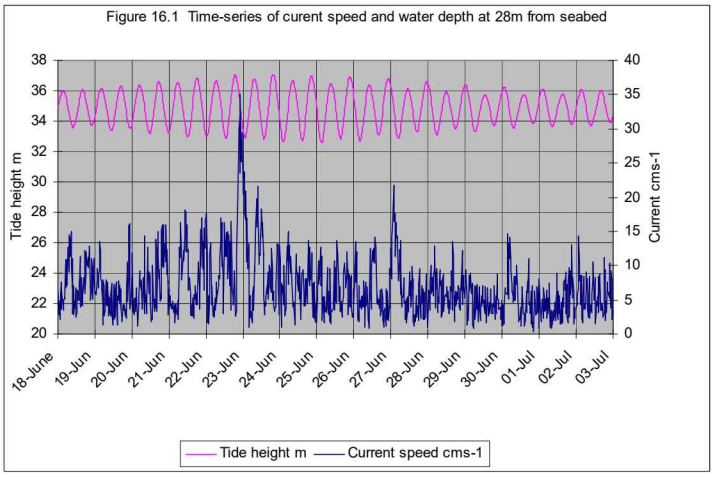
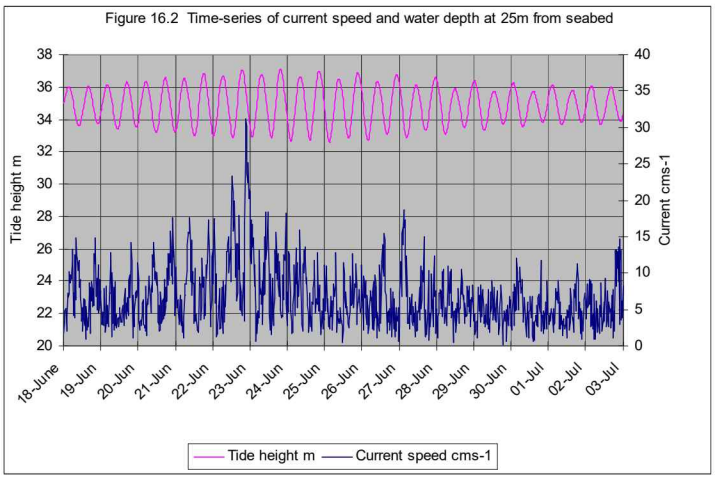


Figure 16.1-16.3: Time series graphs of current speed and tidal height at selected depths from seabed

Trilleachan-Mhor O/S Grid Ref NB 20840 07489
From 00:00 18.06.05 to 00:00 03.07.05 (GMT); 15 days.





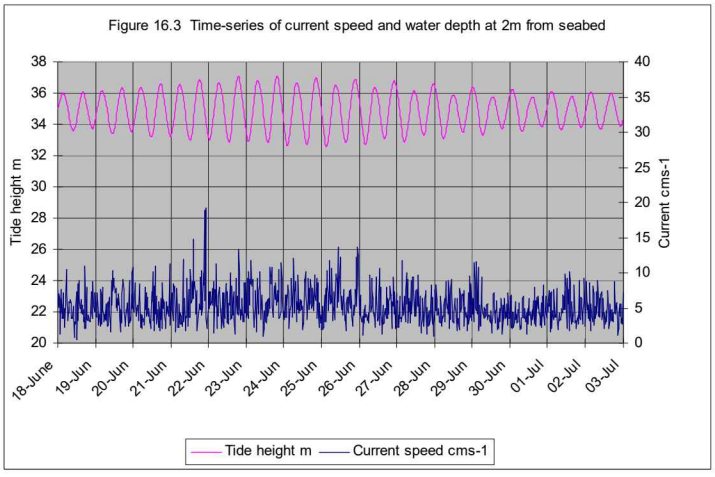
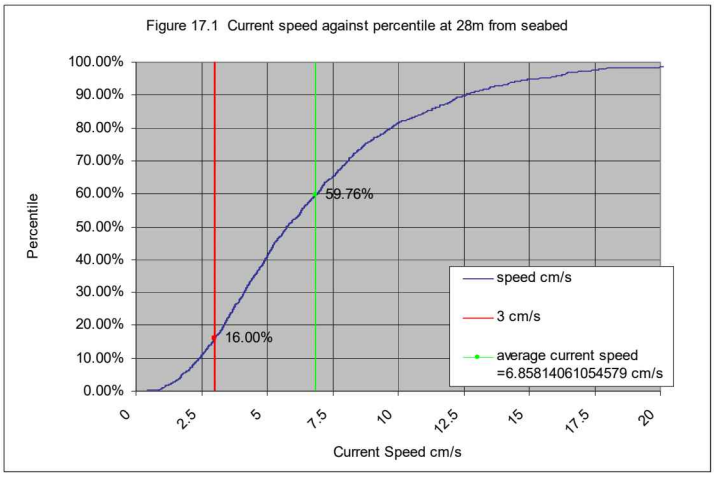
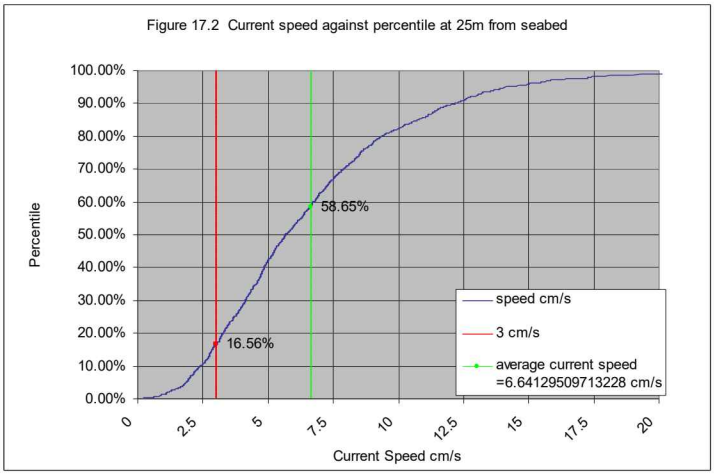


Figure 17.1-17.3: Current speed against percentile graphs at selected depths from seabed (m).

Trilleachan-Mhor O/S Grid Ref NB 20840 07489
From 00:00 18.06.05 to 00:00 03.07.05 (GMT); 15 days.





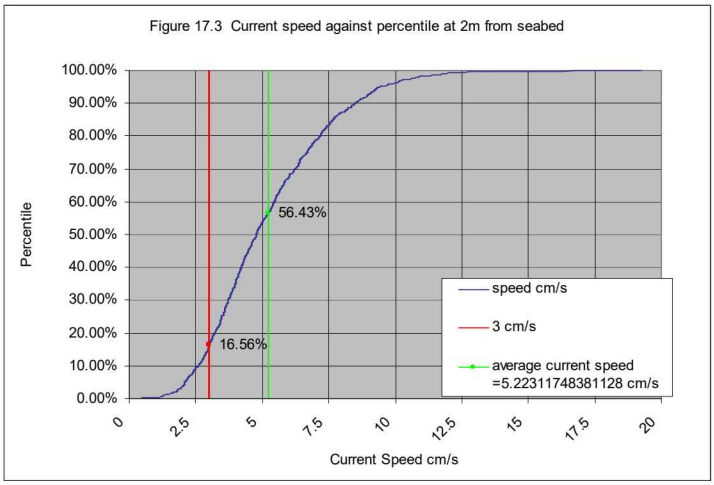


Figure 18: Heading, pitch and roll of ADP

Trilleachan-Mhor O/S Grid Ref NB 20840 07489
From 00:00 18.06.05 to 00:00 03.07.05 (GMT); 15 days.

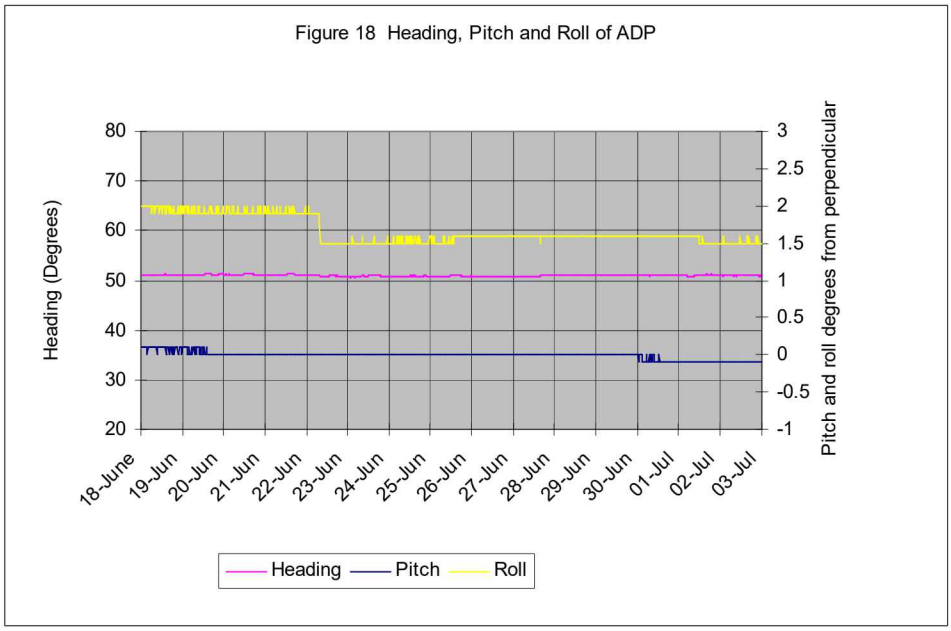


Table 2: Data Analysis

	28m from seabed (shallowest)	25m from seabed	2m from seabed (deepest)
Mean current speed	6.9cms^{-1}	6.6cms^{-1}	5.2cms^{-1}
Ranked percentage of mean speed	60%	59%	56%
3cm/s as a ranked percentage	16.00%	16 %	16%
Residual current speed: direction:	2.70cms^{-1} 187^{0}	2.10cms^{-1} 187^{0}	1.00cms^{-1} 302^{o}
Major axis of tidal current ellipse	175^{o}	175^{o}	5^{o}
Vector components of residual current speed	U: 0.026ms^{-1} V: 0.005ms^{-1}	U: 0.021ms^{-1} V: 0.004ms^{-1}	U: 0.004ms^{-1} V: -0.009ms^{-1}
Vector components of tidal current amplitude	U: 0.101ms^{-1} V: 0.043ms^{-1}	U: 0.096ms^{-1} V: 0.045ms^{-1}	U: 0.062ms^{-1} V: 0.051ms^{-1}

Appendices

Table 3: Equipment Specifications

Nortek Doppler current meter

	Accuracy	Precision	Resolution	Range
Speed	0*	0.98cm/s	0.1cm/s	0-10 m/s
Direction	0*	<0.2^{o}	0.1^{o}	0-360^{o}
Pressure	0.25% FS	<0.005% FS	0.005% FS	0-100 m
Tilt/roll	0.2^{o}	<0.1^{o}	0.1^{o}	0-30^{o}
Temperature	0.2^{o}C	<0.01^{o}C	0.01^{o}C	-4 to 30^{o}C

* Doppler units in theory 100% accurate, i.e. no difference between the true value and the instrumental value.

FS is full scale, which means that 0.005% FS of a 100 meter sensor is 5 mm.

ADCP ctl file

File ----------> TMR05002.ADP
FileSize (bytes) ----------> 948478
Number of profiles --------> 1687
Time of first profile -----> 2005/06/17 23:40:00
Time of last profile -----> 2005/07/11 09:40:00

NDP Hardware Configuration

SoftwareVerNum ----------> 2.6
SerialNumber ----------> N4724
NdpType ----------> 500 kHz
Nbeams ----------> 3
VertBeam ----------> NO
SlantAngle ----------> 25
SensorOrientation----------> UP
CompassInstalled ----------> YES
RecorderInstalled ---------> YES
TempInstalled ----------> NO
PressInstalled ----------> YES
Transformation Matrix -----> 1.577 -0.789 -0.789
-----> 0.000 -1.366 1.366
-----> 0.368 0.368 0.368

NDP User Setup

DefaultTemp ----- (deg C) -> 10.00
DefaultSal ------ (ppt) ---> 35.00
DefaultSoundSpeed (m/s) ---> 1489.80
Ncells ----------> 40
CellSize -------- (m) -----> 1.00
BlankDistance --- (m) -----> 1.00
SensorDepth ----- (m) -----> 0.00
TempMode ----------> 1
PingInterval ---- (s) -----> 0.00
AvgInterval ----- (s) -----> 320
ProfileInterval - (s) -----> 1200
BurstMode ----------> DISABLED
BurstInterval --- (s) -----> 1200
ProfilesPerBurst ----------> 1
CoordSystem ----------> ENU
OutMode ----------> AUTO
OutFormat ----------> BINARY
RecorderEnabled ----------> ENABLED
RecorderMode ----------> NORMAL
DeploymentMode ----------> ON
DeploymentName ----------> TMR05
Comments:

Cell #	Depth (m) (relative to sensor)
1	-2.00
2	-3.00
3	-4.00
4	-5.00
5	-6.00
6	-7.00
7	-8.00
8	-9.00
9	-10.00
10	-11.00
11	-12.00
12	-13.00
13	-14.00
14	-15.00
15	-16.00
16	-17.00
17	-18.00
18	-19.00
19	-20.00
20	-21.00
21	-22.00
22	-23.00

23	-24.00
24	-25.00
25	-26.00
26	-27.00
27	-28.00
28	-29.00
29	-30.00
30	-31.00
31	-32.00
32	-33.00
33	-34.00
34	-35.00
35	-36.00
36	-37.00
37	-38.00
38	-39.00
39	-40.00
40	-41.00

Calibration

Calibration test were carried out on the equipment;

GPS

Site Pier	GPS reading	Accuracy
Start	NB 19652 05992	<5m
Finish	NB 19653 05992	<5m

ADCP
Tests carried out on site for heading pitch and roll, and temperature on the ADCP Systems Test program. All appeared to function satisfactory. No data collected to verify this test.