



23rd February 2022

Modelling Data Collection Report

Meil Bay

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Summary

A hydrographic survey was carried out by Cooke Aquaculture Scotland for a proposed variation to an existing marine caged fish farm site, Meil Bay, located off the east coast of the Orkney mainland.

An acoustic profiling current meter was deployed at the proposed site for 112 days, from the 15th of September 2021 to the 5th of January 2022, from which a 90-day subset was selected. The data presented is considered representative of the period sampled and suitable for determining the impacts due to solid and solute wastes arising from farm operations.

Sensor records confirm that there were several minor disturbances around the mooring during the deployment that resulted in pitch, roll and heading changes, however these variations remained well within the post-processing correction limits and do not cause any deterioration in the data.

The current meter dataset describes an area with generally flow velocities and a relatively uniform vertical structure, where mean velocities through all depth bins was $\sim 0.03\text{m/s}$. Semi-diurnal patterns are present within the current data and 6-7 spring/neap cycles were observed. Residual current magnitudes are greatest near the bed, contributing $\sim 58\%$ to the mean velocity values. Near the bed residual current velocities decrease to $\sim 14\%$ of mean current speeds.

Due to the low average flow speeds, it is expected that this site will be classified as moderately quiescent and depositional. Several short-lived, high-energy events were recorded throughout the deployment, indicating some periodic resuspension/dispersive events are likely to take place.

Data quality parameters indicate that current speed and direction estimates should be of sufficient precision for modelling operational impacts.

1. Quality assurance statement

Cooke Aquaculture Scotland confirms the collection, analysis and reporting of all information is attested by a suitably qualified person and is completed to a consistently high standard, to ensure the data presented is representative of the conditions at the site. This is in line with the current SEPA standards outlined in the 2019 Regulatory Guidance documents (SEPAa & SEPAb).

2. Site description

Meil Bay is an existing, consented site (CAR/L/1003888) operated by Cooke Aquaculture Scotland. The site is located in the Bay of Meil, on the east coastline of the Orkney mainland (Figure 1). Currently, the site has a maximum consented biomass of 884 tons across 10 pens of circumference 100m and net depth 6m arranged in 2 x 5 pattern on 60m mooring grids. This provides a stocking density of 18.515kg/m^3 during peak biomass.

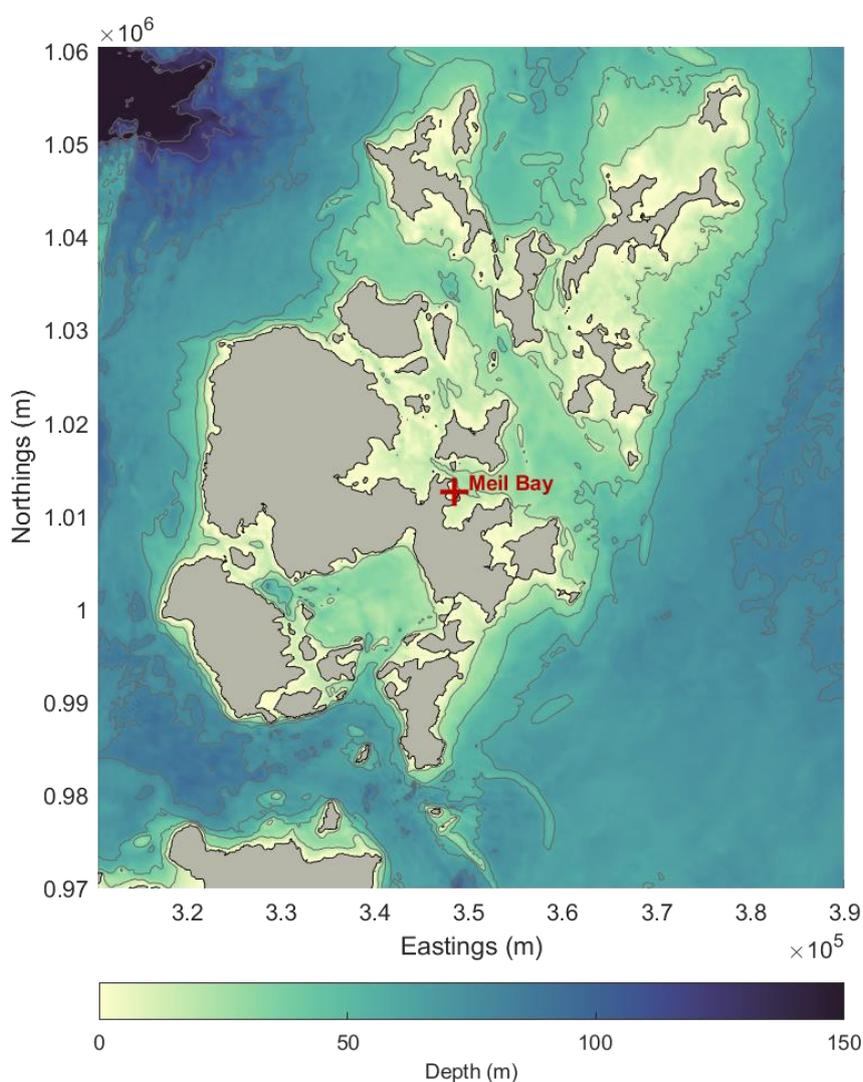


Figure 1. Site location (red cross) and bathymetry with depth contours at 20m intervals.

The proposed development at Meil Bay expands and repositions the existing site. An additional 6 100m circumference, 6m deep pens are added to the existing 10, creating a 2 x 8 layout arranged in 60m mooring grids. The expanded site is relocated 200m to the NW of the existing site in a deeper, less constrained location closer to the mouth of the bay (348439.6396 E, 1012644.2477N). Benthic modelling using the SEPA default NewDepomod model revealed a maximum biomass of 1410 tons at the newly proposed site was compliant with all EQS rules. This provides a stocking density of 18.46kg/m³ during peak biomass. Further information on the existing and proposed site infrastructure and pen layout is presented in Table 1.

Table 1 – Site infrastructure and pen layout.

	Meil Bay (Existing)	Meil Bay (Proposed)
Consent number	CAR/L/1003888	
Company	Cooke Aquaculture Scotland	Cooke Aquaculture Scotland
Receiving water	Shapinsay Sound	Shapinsay Sound
Site centre (OSGB36)	348452.07E, 1012342.29N	348439.6396 E, 1012644.2477N
Current meter location (OSGB36)/year of deployment	348378N, 1012552N/2018	348388E, 1012558N/2021
Distance to shore (km)	0.35	0.5
Average water depth (m)	9.6	12.1
Maximum biomass (t)	884	1410
Total number of pens	10	16
Number of pen groups	1	1
Formation	2 x 5	2 x 8
Pen group orientation (°)	23	36
Pen shape	Circular	Circular
Pen circumference (m)	100	100
Mooring grid (m)	60	60

3. Scope of report

3.1 Required data

Benthic sampling will be carried out to measure Infaunal Quality Index (IQI). This can then be used to assess the environmental performance of the site along with the calibration of future modelling work.

3.2 Existing data

Hydrographic data collected in 2021 has been assessed with a 90-day subset of data being selected for analysis. UK Hydrographic Office data (UKHO, 2021) was used to create the bathymetry around the site for future modelling work.

4. Methods

4.1 Hydrographic measurements

A hydrographic survey was undertaken for the proposed site. A Nortek Signature 500kHz (serial no. 101510) Acoustic Doppler Current Profiler (ADCP) was deployed between 15th September 2021 and the 5th of January 2022 at 348388E, 1012558N, ~100m for the proposed site centre. This deployment provided ~112 days of useable data.

The sensor was mounted in a weighted mooring frame with a gimble and deployed in a specific location to avoid interference from existing site infrastructure or other potential risks to data validity. The transducer head is located 0.62m from the seabed. More detail on sensor configuration is given in table 2.

Table 2. Sensor configuration for the deployment.

Signature 500 – Serial no. 101510	
Site name	Meil Bay
Measurement interval (minutes)	10 (600 secs)
Average interval (minutes)	5 (300 secs)
Number pings	480
Orientation	Up looking
Salinity (ppt)	35
Cell size (m)	1
Number cells	21

Coordinate system	BEAM
Blanking distance (m)	0.5
Vertical precision (cm/s)	0.27
Measurement load (%)	40

4.2 Hydrographic data: 15/09/2021 – 05/01/2022

The data recorded by the ADCP allows the calculation of flow profiles every 600 seconds. These results were logged on an internal memory card. The specific parameters logged by the ADCP, alongside their accuracy, resolution and range are outlined in table 3.

Table 3. ADCP data collection parameters and specifications.

	Accuracy	Resolution	Range
Speed	0.3% of 0.3cm/s	0.1cm/s	2.5m/s
Compass	2° tilt <30°	0.01°	-
Tilt	0.2° tilt <30°	0.01°	-
Pressure	0.1% full scale	-	0-100m
Heading	± 3° (dynamic)	0.01°	360° all axes
Pitch/roll	± 2° (dynamic)	0.01°	± 90° (p) ± 180° (r)
Temperature	0.1°	0.01°	-4-+40°

4.3 Data processing

Raw data recorded on the Signature500 was downloaded as binary data files using the Nortek AS Signature Deployment programme. The Deployment programme was then used to convert and export the binary files into a .mat file format, suitable for reading into MATLAB.

The averaged current data was assessed in Signature Viewer, a post processing software programme, to ensure the data was of high quality. The data was then imported into MATLAB, where in-house scripts performed quality control (QC) and post processing. These QC checks included assessment of:

- Heading, Pitch and Roll ($^{\circ}$) – checking the meter has an upward orientation and limited frame movement during the survey using a threshold exceedance method with a range of $\pm 20^{\circ}$.
- Pressure record (m) – comparing the depth recorded by the meter with the bathymetry for the area. Clear spring and neap tides observed in the pressure record with no unusual increases or decreases in the record.
- Amplitude (Signal Strength - dB) – should be decreasing with distance from the sensor. Be aware of any unusual spikes, large increases or the amplitude becoming constant. Dramatic increases in amplitude will be seen when the signal meets a boundary such as the surface or seabed. Minimum amplitude threshold = 30dB.
- Correlation (%) – quality measure of velocity data, a decrease in correlation means a decrease in data accuracy. Minimum correlation threshold = 50% of the maximum correlation.

Any data out with the QC parameters were removed and replaced with NaN values. These were later interpolated to repair any missing values. Only depth cells with less than 5% missing/repared data are considered for use in further modelling work.

5. Site infrastructure

The proposed site infrastructure at Meil Bay consists of 16 (2x8) 100m circumference, 6m deep pens arranged on a 60m mooring grid. This pen layout, alongside the ADCP deployment location, is illustrated in figure 2.

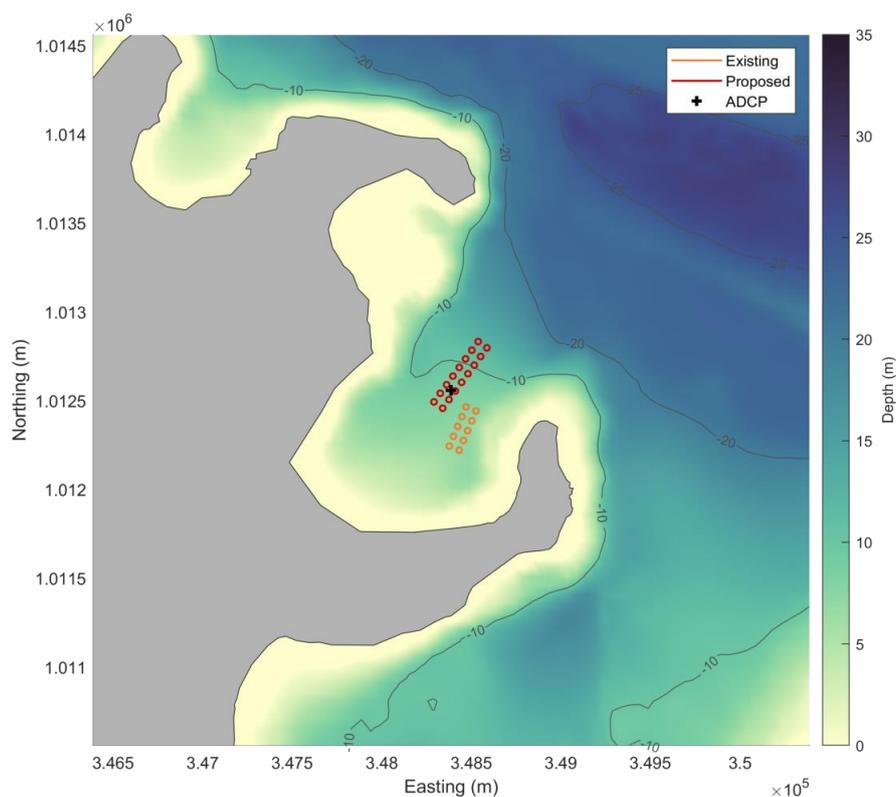


Figure 2. Existing (orange) cage layout proposed (red) cage layout and ADCP location (black +) at Meil Bay.

The modification to the existing Meil Bay sites allows the site to be moved into deeper, higher velocity water outside the most sheltered confines of the bay. This creates more dispersive conditions at the expanded proposed site, likely resulting in a more sustainable operation.

6. Bathymetry

Figure 2 shows the bathymetry around the site sourced from UKHO (UKHO, 2021). This shows a rapidly shoaling seabed with decreasing distance to the shore within Meil Bay. The average depth at the existing site is <10m, whereas the proposed site sits in deeper water further outside of the bay, with an average depth of ~12m. The UKHO bathymetry data will be used for modelling purposes

7. Flow data

The profiling device was deployed on the seabed at (OSGB 1936) 348388E, 1012558N (figure 2) for 112 days from the 15th of September 2021 to 5th January 2022, with usable data recorded across the full deployment. During the recording period a mean water depth of 12.1m was recorded. The quality control process identified 100 pitch and roll exceedances and 96 water column errors (0.098%) within the full data set.

To comply with SEPA's NewDepomod regulatory modelling guidelines, a total of 90 days of current meter data must be used. Applying a timestep of 600 seconds, this provides a total number of 12,960 timesteps forming 90 days of data. The length of the usable data set exceeds the 90-day minimum by ~22 days. The 90-day period selected was from 07/10/2021 10:30 to 05/01/2022 10:30. Within this 90-day subset, no pitch and roll exceedances or water column errors were identified.

The sensor heading, pitch and roll for the 90-day period are shown in Figure 3. There are several disturbances in the sensor variables occurring on the 14/10/21, 8/12/21, 23/12/21, 26/12/21 and 28/12/21. However, at these times the variations in pitch, roll and heading suggests the ADCP gimble remained stable with only small fluctuations recorded that were well within the operating constraints advised by SEPA. These measurements suggest it is unlikely that any significant frame movements occurred.

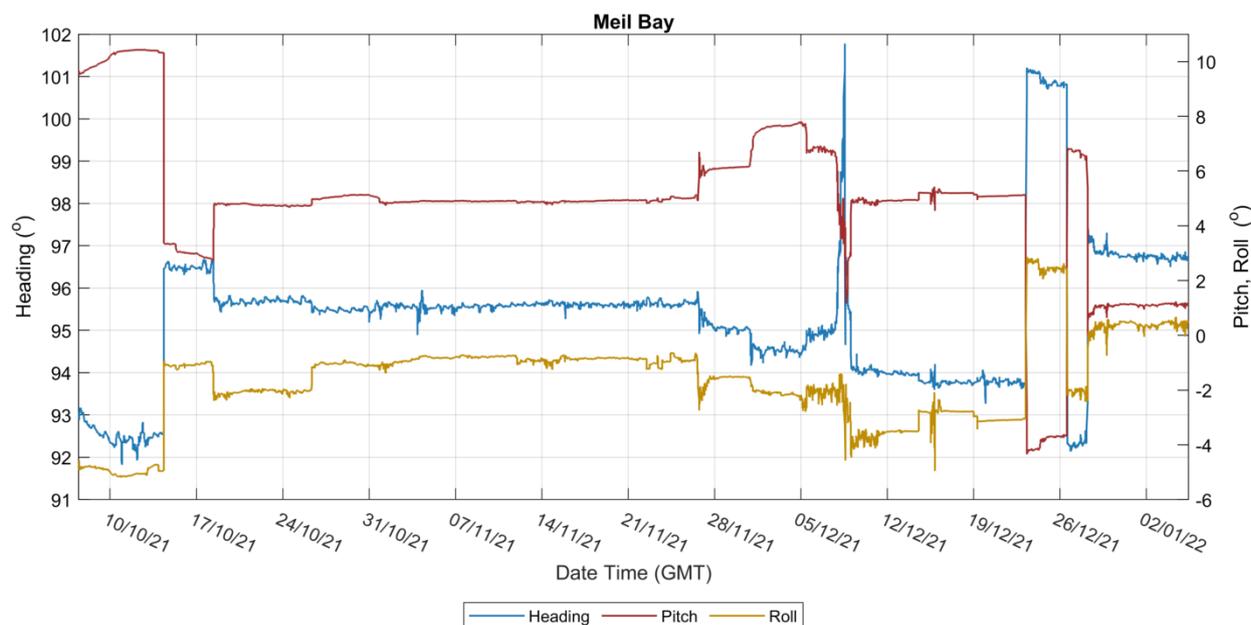


Figure 3. Sensor heading, pitch and roll for the 90-day period.

The flow statistics over the 90-day deployment are given in Table 4. Typically, the site experiences low flow speeds, with mean velocities $<0.04\text{m/s}$. However, several higher energy events occur throughout the deployment where flow speeds at all depths exceed 0.1m/s , resulting in maximum recorded velocities of 0.19m/s . Little vertical structure is observed in velocity magnitudes, indicative of shallow well-mixed sites. The ranked percentage of velocity 0.03 , 0.045 and 0.095m/s represents the proportion of data below these speeds. This indicates whether a site is quiescent and determines the proportion of resuspension velocities. This data represents a site with high quiescent tendencies and a small proportion of resuspensions events, characteristic of a weakly flushed site. Residual currents are strongest near the surface and reduce in magnitude towards the bed. The direction of the residual currents is predominantly southerly in the upper water column and south-easterly near the bed.

Table 4. Flow statistics

	Near Surface	Cage Bottom	Near Bed
Height from seabed (m)	7.62	6.62	1.62
Depth Cell	7	6	1
Mean Speed (m/s)	0.0345	0.0336	0.0392
Ranked Percentage at 0.03m/s (%)	46.95	49.24	35.8
Ranked Percentage at 0.045m/s (%)	75.63	76.95	65.97

Ranked Percentage at 0.095m/s (%)	99.01	99.14	98.89
Maximum Speed (m/s)	0.1906	0.1992	0.1852
Residual Speed (m/s)	0.0202	0.0183	0.0055
Residual Direction (°)	190.37	190.75	130.39

The near surface, cage bottom and near bed flow conditions are presented in Figures 4-7. Plot descriptions:

- A - Percentile current speed with 0.03, 0.045 and 0.095m/s indicated by black cross markers.
- B - Polar scatter plot of all speed and direction data points with residual marker in red.
- C - Percentage occurrence flow direction.
- D - Cumulative 3-dimensional particle displacement.
- E - Time series of current speed and water level.
- F - Time series of direction and water level.

Near Surface: $z = 7.62\text{m}$ (Cell = 7)

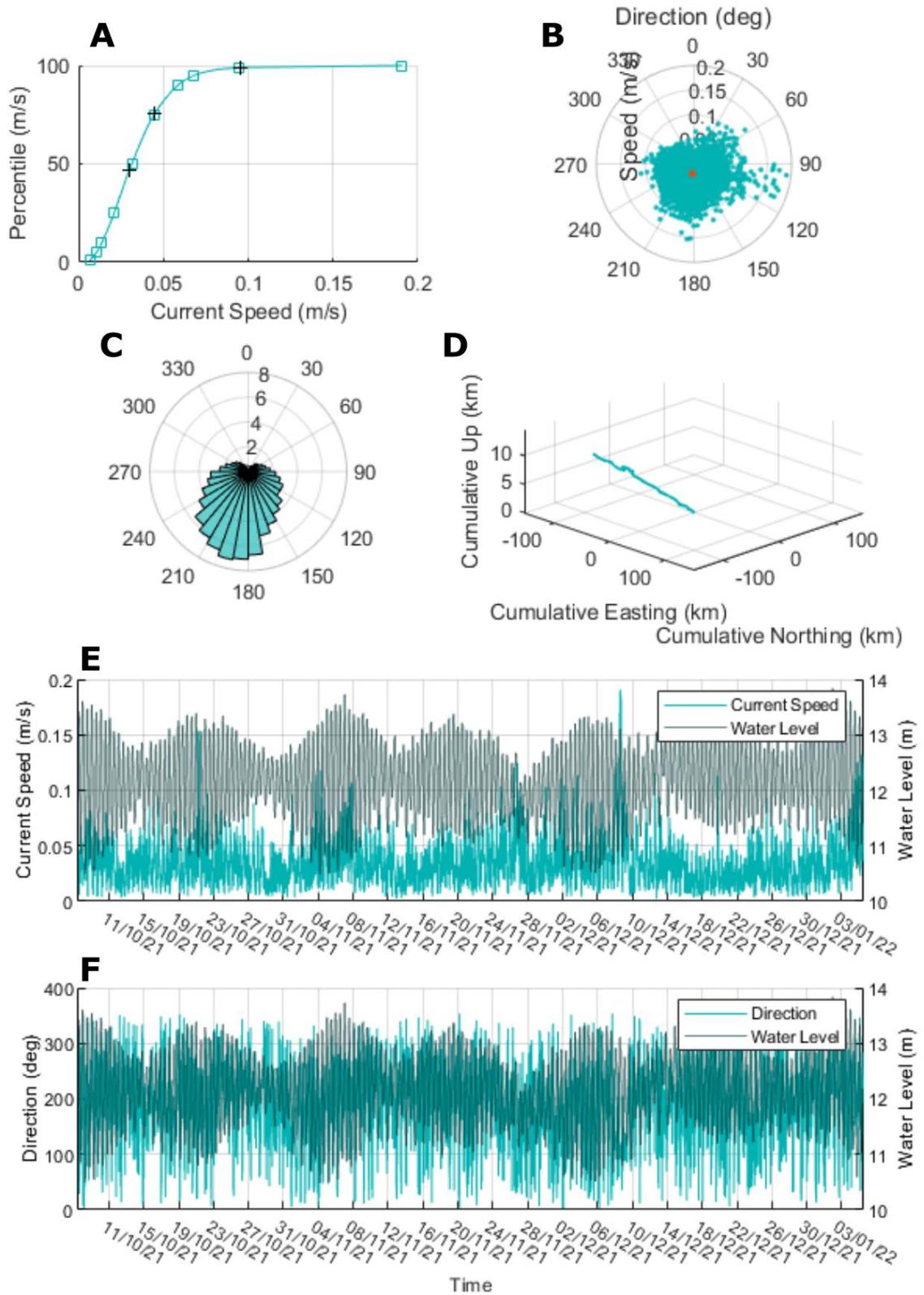


Figure 4. Near surface flow data.

Cage Bottom: z = 6.62m (Cell = 6)

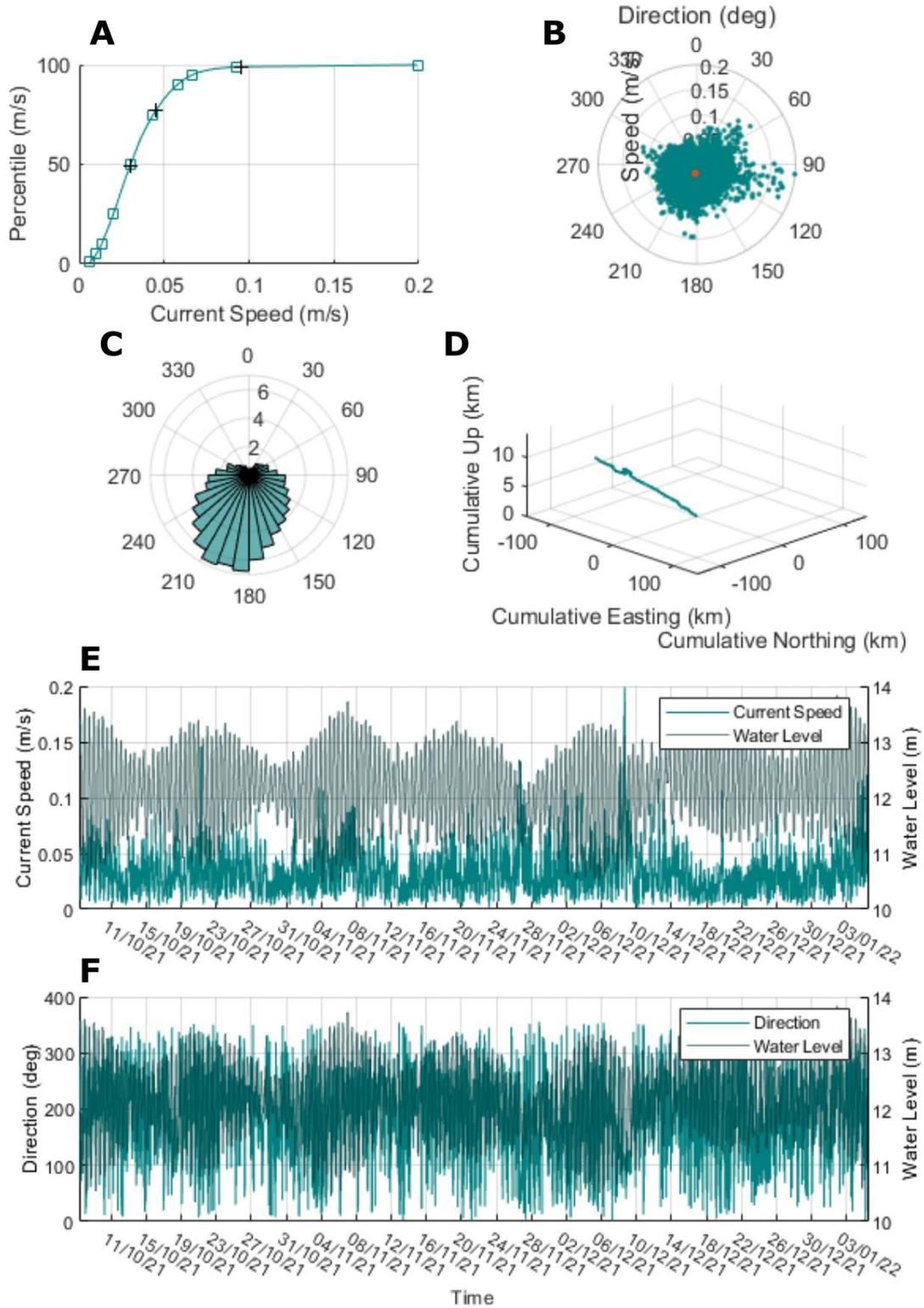


Figure 5. Cage bottom flow data.

Near Bed: z = 1.62m (Cell = 1)

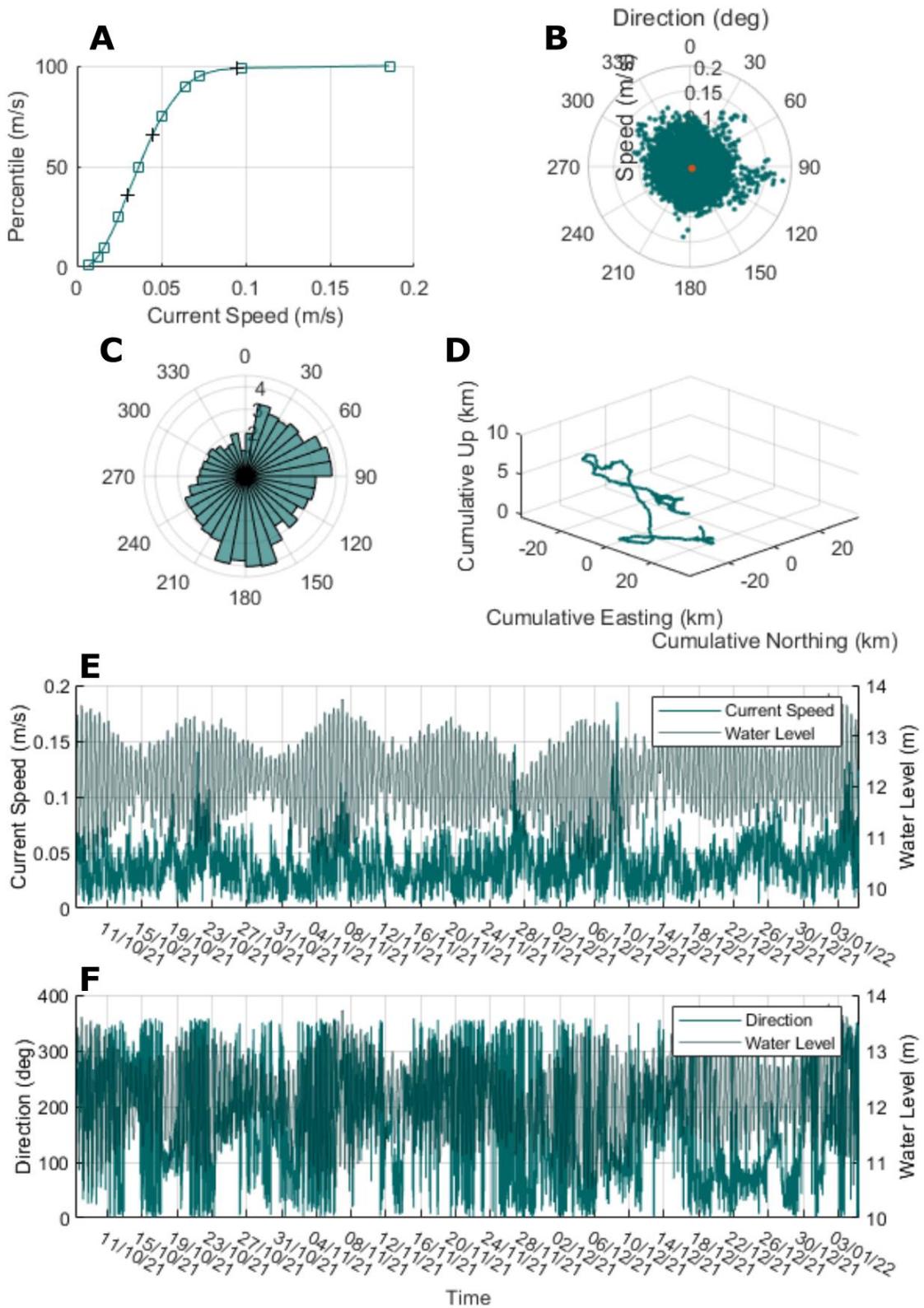


Figure 6. Near bed flow data.

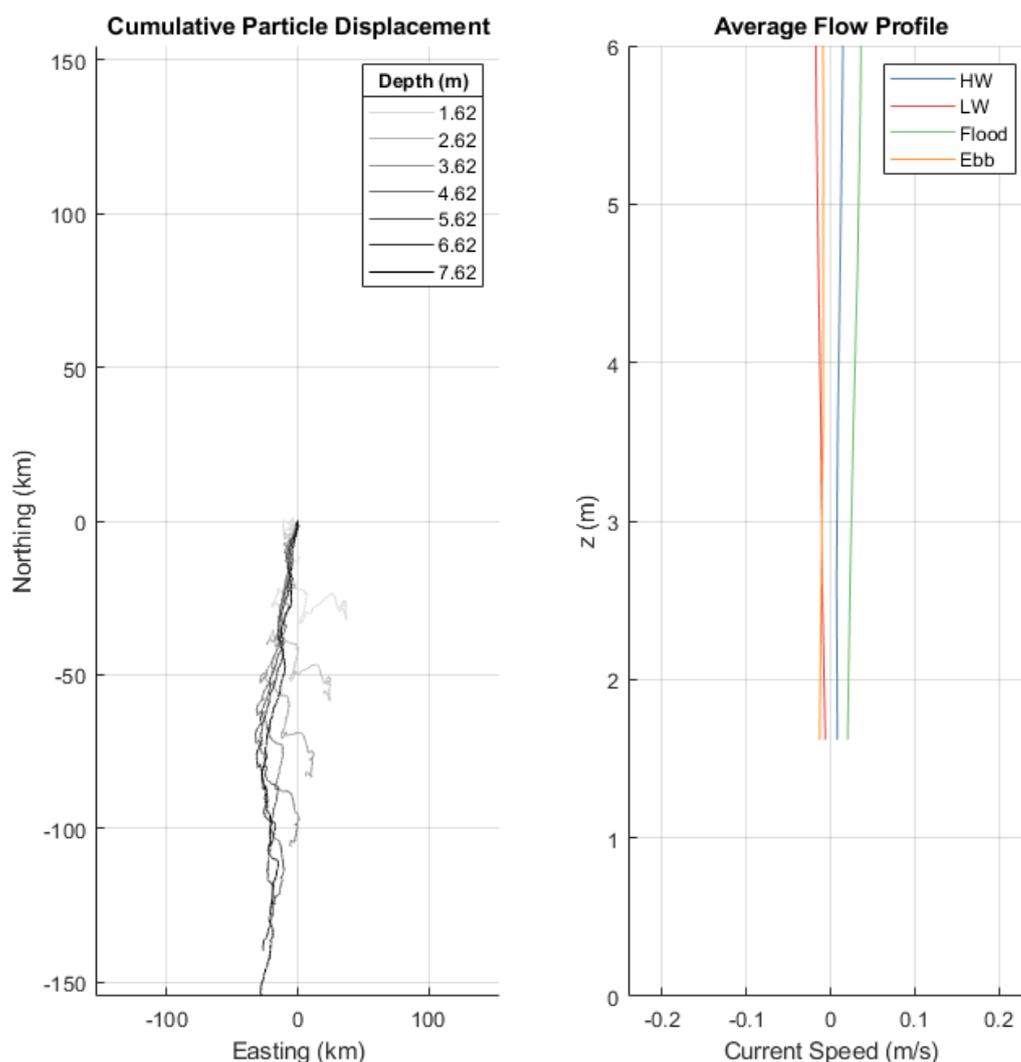


Figure 7 – Left: Cumulative particle displacement with depth. Right: Average velocity depth profile for high water (HW), low water (LW), flood tide (Flood) and ebb tide (Ebb).

8. Discussion

An ADCP was deployed near the proposed site centre for over 90-days. During this time, the sensor recorded several gimbal and heading movements. 100 timesteps where pitch and roll values exceeded SEPA advised thresholds of 20° were recognised. Additional quality control techniques found 0.098% errors within the full deployment dataset. The extracted 90-day sub-dataset included no pitch, roll and heading exceedances or measurement errors. Overall, this suggests a successful deployment with results suitable for use in further applications.

The site experiences mean velocities of approximately 0.03m/s at all depth intervals. Average velocity shows little variation with depth, creating a relatively uniform vertical profile with little shear. Residual currents show an increase in magnitude closer to the surface, making up approximately 54-58% of the mean velocity in the near surface and cage

bottom depth layer. Near the bed residual current contribution decreases to 14%. A southern residual current direction was recorded in the near surface and cage bottom depth bins, whereas near the bed a south-easterly residual direction was observed.

The hydrographic results can be used to classify the site in terms of flushing, quiescence and resuspension. The mean current speed is slightly greater than 0.03m/s in all depth layers, making Meil Bay a weakly flushed site (table XX).

Table XX. Flushing characteristics based on mean current speed.

Mean Current Speed (m/s)			
>0.1m/s	0.05-0.1m/s	0.03-0.05m/s	<0.03m/s
Strongly flushed	Moderately flushed	Weakly flushed	Quiescent

The quiescent periods of the measured data show values ranging from 36% to 49%, making the site moderately quiescent.

Table XX. Degrees of quiescence based on percentage current speeds below 0.03m/s.

Quiescent Period (0-0.03m/s)		
>50%	30-50%	<30%
Highly quiescent	Moderately quiescent	Slightly quiescent

Velocities were below 0.095m/s approximately 99% of the time, meaning few resuspension events occurred.

Table XX. Resuspension characteristics based on percentage current speeds below 0.095m/s.

Resuspension (<0.095m/s)		
>95%	80-95%	<80%
Depositional/Quiescent	Partially resuspensive	Highly resuspensive

These parameters classify the site as a moderately quiescent, depositional site.

9. Equipment list

- Garmin eTrex 10 handheld GPS
- Nortek Signature 500kHz Acoustic Doppler Current Profiler (Serial no. 101510)

10. Calibration reports

Below are the calibration documents for the Nortek Signature 500kHz ADCP (Serial no. 101510) used in the Meil Bay deployment.

Final test checklist AD2CP



Veigrotaas 2
N-1281 B&S
Norway
Tel: +47 8717 8800
Fax: +47 8713 8770
Inquiry@nortek-as.com
www.nortek.no

Order number:
42931-1-77

Name: **SIGNATURE 500**
Instrument serial number: **101510**
Frequency: **500 kHz** Main board: **AD2CP-1744**
Firmware version: **1.4.5217.2211-4/169**

Label checked OK
Dock test OK
Baudrate 115200 OK

Comments:

Tilt check
 Pitch up
 Roll up
 Status bit
 Pitch down
 Roll down
pitch & roll within +/- 0.2 °

Clock
 Set clock **UTC**
Heading
 Up
 Down
tolerance: +/- 2 °

Pressure
Pisorttemp OK
tolerance: +/- 0.1 % of
300 m

Temperature
 OK
tolerance: +/- 0.1 °

Beam check

Correct order	Beam Imp	Noise floor	Amplitude in tank	Range
Beam 1 <input checked="" type="checkbox"/> OK	<input type="checkbox"/> Ω	26 dB	> 80 dB	<input checked="" type="checkbox"/> OK
Beam 2 <input checked="" type="checkbox"/> OK	<input type="checkbox"/> Ω	26 dB	> 80 dB	<input checked="" type="checkbox"/> OK
Beam 3 <input checked="" type="checkbox"/> OK	<input type="checkbox"/> Ω	26 dB	> 80 dB	<input checked="" type="checkbox"/> OK
Beam 4 <input checked="" type="checkbox"/> OK	<input type="checkbox"/> Ω	26 dB	> 80 dB	<input checked="" type="checkbox"/> OK
Beam 5 <input checked="" type="checkbox"/> OK	<input type="checkbox"/> Ω	26 dB	> 80 dB	<input checked="" type="checkbox"/> OK

Velocity direction

XYZ coordinate system	ENU coordinate system
X <input checked="" type="checkbox"/> OK	E <input checked="" type="checkbox"/> OK
Y <input checked="" type="checkbox"/> OK	N <input checked="" type="checkbox"/> OK
Z <input checked="" type="checkbox"/> OK	U <input checked="" type="checkbox"/> OK
Z ₀ <input checked="" type="checkbox"/> OK	U ₀ <input checked="" type="checkbox"/> OK

Head file
 Headfile checked
 Saved as read only

Serial communication
 RS422
 RS232 **N/A**

Recorder erased
 OK
Rec size: **16GB**

Ethernet
MAC address: **8C:68:78:00:06:D0**
Static IP address:
Set host name: **101510**

DHCP enabled
FTP OK

Licenses

Averaging mode <input checked="" type="checkbox"/>	Wave mode <input checked="" type="checkbox"/>	Vertical velocity <input type="checkbox"/>	64GB recorder <input type="checkbox"/>	Calibration license erased <input checked="" type="checkbox"/>
Burst Five beams <input checked="" type="checkbox"/>	Echo Sounder <input type="checkbox"/>	Dual frequency low <input type="checkbox"/>	128GB recorder <input type="checkbox"/>	Production license erased <input checked="" type="checkbox"/>
Bottom track <input type="checkbox"/>	Ice Measurement <input type="checkbox"/>	Dual frequency high <input type="checkbox"/>	256GB recorder <input type="checkbox"/>	Default configuration set <input checked="" type="checkbox"/>
High Resolution <input type="checkbox"/>	Altimeter <input type="checkbox"/>	16GB recorder <input checked="" type="checkbox"/>		

Cable/Harness
Cable Communication Harness Communication
Battery Battery

Electrical isolation test
50V Ok

External sensors

Power down
 OK

Date
Day: **23** Month: **07** Year: **2019**

Instrument Information

Customer Reference No.	42931-1-77
RMA No.	0
Instrument Type	Signature500
Instrument Frequency	500 kHz
Instrument S/N	101510
Head S/N	D-1510
Interface Board S/N	1744
Interface Board Mfr. S/N	4MO0613760058
Digital Board Mfr. S/N	4MO0587840036
Analog Board Mfr. S/N	4MO0619860015
Sensor Board Mfr. S/N	4MO0615010019
Interface Board Rev.	H-2
Digital Board Rev.	I-3
Analog Board Rev.	G-1
Sensor Board Rev.	I-0

Calibrations and tests performed

Pressure	Passed
Tilt and Compass	Passed

All the tested values are within Nortek AS specifications

July 23, 2019
 Date

11. List of data files and description

Hydrographic data sheets (NS, CB, NB)

- CurrentMeterData_MeilBay_Bottom2021
- CurrentMeterData_MeilBay_Middle2021
- CurrentMeterData_MeilBay_Surface2021

Raw instrument files

- S101510A010_MeilBay.cfg
- S101510A010_MeilBay.ad2cp
- S101510A010_MeilBay_0001.ad2cp
- S101510A010_MeilBay_avgd.ad2cp

12. References

Scottish Environment Protection Agency (SEPAa) (2019) “Regulatory Modelling Process and Reporting Guidance for the Aquaculture Sector”. Version 1.1. Available at: <https://www.sepa.org.uk/media/450278/regulatory-modelling-process-and-reportingguidance-for-the-aquaculture-sector.pdf>

Scottish Environment Protection Agency (SEPAb) (2019) “Regulatory Modelling Guidance for the Aquaculture Sector” Version 1.1. Available at: <https://www.sepa.org.uk/media/450279/regulatory-modelling-guidance-for-theaquaculture-sector.pdf>

UK Hydrographic Office (2021) Marine Data Portal (Accessed 05/2021) Available at: <https://datahub.admiralty.co.uk/portal/apps/sites/#/marine-data-portal>