Immingham Green Energy Terminal

TR030008

Volume 6

6.4 Environmental Statement Appendices

Appendix 16.C: AWAC Deployment: Hydrodynamic Study

Planning Act 2008

Regulation 5(2)(a)

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009 (as amended)

September 2023

Infrastructure Planning

Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009 (as amended)

Immingham Green Energy Terminal

Development Consent Order 2023

6.4 Environmental Statement Appendices

Appendix 16.C: AWAC Deployment: Hydrodynamic Study

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Summary

As part of long-term development strategies, Associated British Ports (ABP) commissioned ABPmer to undertake a hydrodynamic survey surrounding the Port of Immingham. An Acoustic Wave and Current (AWAC) device and salinity and turbidity sensor were deployed on a seabed frame at a subtidal location southeast of the Immingham Oil Terminal (IOT).

The seabed frame was deployed for a 6-month period between 12 August 2022 and 03 March 2023 which captured the winter months to observe the greatest expected wave activity. The deployment was split into 4 periods, in between which the equipment was recovered for a data download and battery change, and immediate redeployment:

Period 1: 12 August 2022 – 01 October 2022;

Period 2: 02 October 2022 – 14 November 2022;

Period 3: 14 November 2022 – 05 January 2023; and

Period 4: 06 January 2023 – 03 March 2023.

Wave conditions (wave height, wave period and wave direction) were recorded at hourly intervals, with current speed, current direction and water turbidity collected at ten-minute intervals.

Raw datasets were processed using several pre-established quality assurance techniques before being exported as finalised datasets for use in both present and future modelling applications.

1. Appendix 16.C: AWAC Deployment: Hydrodynamic Study

1.1. Introduction

1.1.1. As part of long-term development strategies, Associated British Ports ("ABP") commissioned ABPmer to undertake a hydrodynamic survey surrounding the Port of Immingham. An Acoustic Wave and Current ("AWAC") device, combined with Salinity and Turbidity sensors were deployed on a seabed frame at a subtidal location southeast of the Immingham Oil Terminal (IOT).

1.1.2. This report provides a summary of the project detailing:

- Survey Methods (Section 2):
  - Equipment used and associated installation parameters;
  - Dates and duration of deployments;
  - Deployment location;
  - Deployment method;
- Data Processing (Section 3):
  - Summary of instrument data processing methodologies;
  - Survey results (Section 4):
  - Summary of data results.

1.2. Survey Methods

Static recording instruments

1.2.1. Static recording instruments were deployed near the IOT as illustrated in **Plate 1-1** and detailed in **Table 1-1**.

1.2.2. The instruments were deployed for a total duration of six months, consisting of four individual deployment periods. Each deployment period (as detailed in Table 1-1) was for approximately 6 weeks ensuring that required parameters were recorded over several full spring/neap cycles whilst simultaneously considering any short-term variations in fluvial input and wave activity.

1.2.3. The specific equipment deployed, and the acquisition parameters are described below (see Annex B for full instrument specifications and Annex C for calibration certificates):

- Nortek 1 MHz Acoustic Wave and Current ("AWAC") instrument was deployed to acquire water level, tidal flow and wave data. Average current flow data over a 60 second burst was acquired at 10-minute intervals at 0.5 m depth bins through the water column. 2,048 wave activity observations were acquired at 2 Hz at 60-minute intervals. The manufacturer's quoted accuracy of the AWAC is:

- Velocity ±1% of measured value ±0.5 cm/s (velocity data provided at 2 decimal places).
- Compass 2° accuracy with resolution 0.1° (direction data provided at 1 decimal place).

- RBR duo TU/DO sensor to acquire near-bed turbidity ("TU") via optical backscatter ("OBS") and dissolved oxygen ("DO"). Sampling was set to acquire at 10-minute intervals, with individual readings taken every 5 seconds over an averaged 1-minute burst.

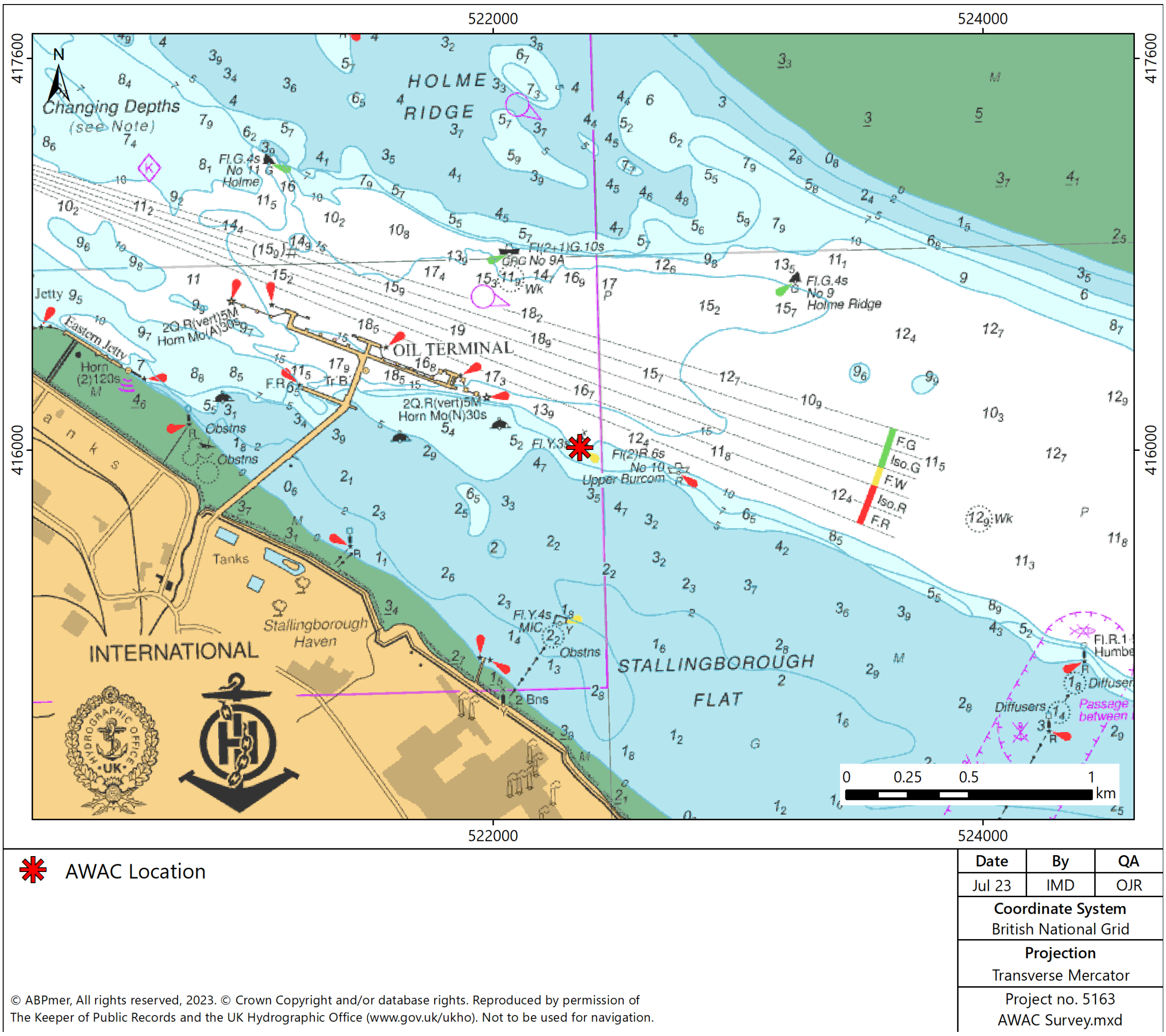


Plate 1-1. Location of static instrument package southeast of IOT

Table 1-1. Coordinates and timings of deployed AWAC, CTD and TU/DO instruments

Data Period	WGS84		OSGB36 (OSTN15)		Deployment Date/Time (GMT)	Recovery Date/Time (GMT)
	Latitude	Longitude	Easting	Northing		
1	53° 37.58025' N	000° 09.08101' W	522356	416008	12/08/2022 06:00	01/10/2022 14:30
2					02/10/2022 10:10	14/11/2022 08:30
3					14/11/2022 14:10	05/01/2023 10:50
4					06/01/2023 11:50	03/03/2023 07:40

1.2.4. In advance of all deployments, the instruments had new batteries installed, internal compass and pressure sensors calibrated, and the required acoustic ping (measurement) intervals were checked in the laboratory prior to being transported to the site. Further acoustic ping checks were conducted onboard the vessel immediately prior to deployment. The internal clocks of the AWAC and CTD/Turbidity sensors were all synchronised to Greenwich Mean Time ("GMT").

1.2.5. The Nortek AWAC (SN: WPR2877) instrument and RBR duo TU/DO (SN: 52601) sensors were secured to a seabed frame and deployed for a six-month period between 12 August 2022 and 03 March 2023.

1.2.6. The deployment coordinates and specific times of recovery and re-deployments are provided in **Table 1-1**.

1.2.7. The seabed frame was deployed and recovered using a deck crane onboard the *UKD Seahorse* workboat. Deployment lines appropriate for the weight of the instrument package were used to aid deployment/recovery. A ground line was run from the frame out to a sinker weight secured to a marker buoy for navigational safety. A schematic of this deployment configuration is shown in Plate 1-2.

1.2.8. A detailed Risk Assessment ("RA") and Safe Systems of Work ("SSOW") was created ahead of the initial deployment. After the first deployment, this was revised to reflect minor changes to the procedures agreed between the ABPmer surveyor and UKD vessel crew onboard the UKD Seahorse.

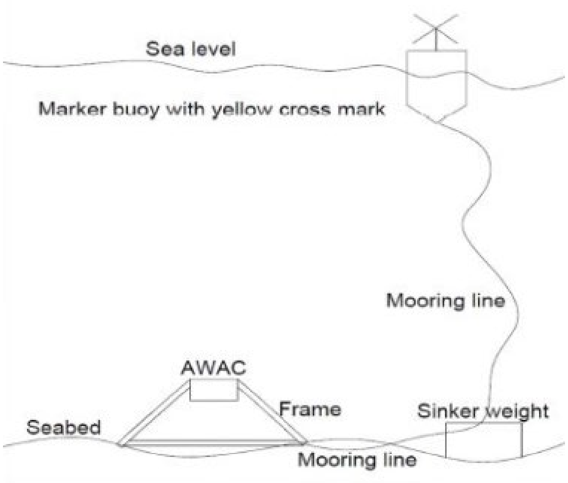
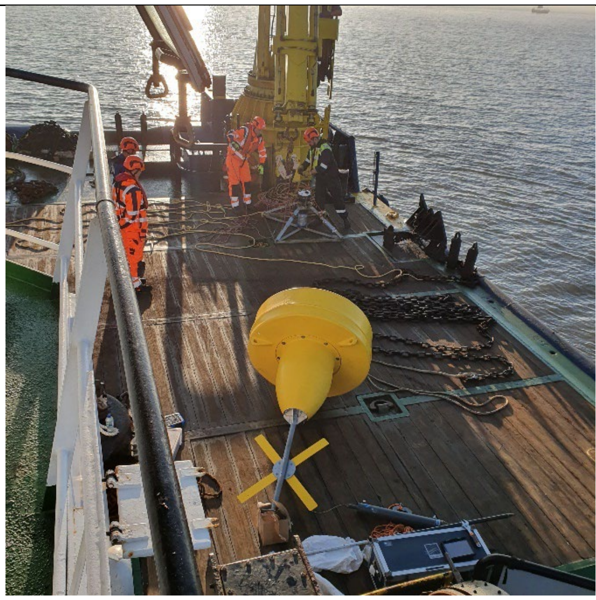
	
Deployment configuration	Frame, sinker weight and mooring lines onboard UKD Seahorse prior to deployment on 12 August 2022

Plate 1-2. Configuration of seabed frame and mooring (left) prior to deployment on 12 August 2022 (right)

Turbidity

1.2.9. Following recovery, the TU/DO sensor was inspected for biofouling. Such activity could affect the reliability of the readings. However, no significant fouling was observed throughout all data periods;

1.2.10. The raw datasets from each period were examined visually in a time-series format to determine any unusual trends, data offsets or data drift. Based on this data inspection, a decision was made about whether the data could be used as primary data; and

1.2.11. Raw OBS readings acquired by the TU/DO sensor was examined with individual readings deemed to be erroneous assigned a flag code within the finalised datasets. If required, information on dredging activity surrounding the Port of Immingham and existing jetties during the deployment periods (supplied by UKD) were also examined (along with observed weather conditions) to explain any prolonged periods of OBS consistently higher than background values.

1.3. Data Processing

1.3.1. Following each recovery and data download, datasets were quality checked and processed according to the following procedures.

Static recording instruments

AWAC

1.3.2. Following recovery, the AWAC sensor was inspected for biofouling. Such activity (either via temporary snagging or progressive build-up) could affect the beam Intensity of the 4 sensors, which can cause a decrease in data quality. However, no significant fouling of the AWAC was observed throughout any of the data periods;

1.3.3. The raw datasets from each period were examined visually in a time-series format to determine any unusual trends, data offsets or data drift. Based on this data inspection, a decision was made about whether the data could be used as primary data;

1.3.4. The raw datasets from each period were then interrogated through the manufacturers' quality/integrity tests to determine whether any parameters (pitch/roll/heading) were outside the specified tolerances (± 5°) for best quality. Any data outside these tolerances were assigned a flag code before being removed from the final datasets (and not included within any statistical analysis);

1.3.5. A calibration of the indicated pressure was then applied in order to consider the instrument height above the seabed, the blanking distance of the instrument's vertical sensor and variations in atmospheric pressure at the time of deployment;

1.3.6. East and North components of current speed at each depth interval (0.5 m) were converted into an absolute current speed and direction for each period, before being depth-averaged throughout the water column;

1.3.7. Current directions were offset from values relative to magnetic north (as indicated by the internal instrument compasses) to values relative to true north using variation values of 0.37° (Period 1, 12 August 2022 to 01 October 2022), 0.42° (Period 2, 02 October 2022 to 14 November 2022), 0.45° (Period 3, 14 November 2022 to 05 January 2023) and 0.48° (Period 4, 06 January 2023 to 03 March 2023), as indicated by the National Oceanic and Atmospheric Administration (NOAA) online calculator for Immingham[1]; and

1.3.8. Hourly wave observations were examined for potentially erroneous or misleading values, which were subsequently assigned a flag code within the finalised datasets. These included:

- Large positive spikes in H_s and H_{max} and/or T_p and T_z as a result of ship wake during the wave sampling period (including very short durations of relatively large vessel-induced waves and/or entrainment of air into the water above the instrument temporarily affecting the quality of the acoustic measurements); and
- Isolated anomalously high T_p and/or T_z values during otherwise benign (i.e. very low H_s and low wind speed) conditions, where residual small amplitude oscillations in water level are identified as large (>10 s) period swell. The values may be a technically correct interpretation of the data, however,

1 Ref 1-1

should not be considered as a distinctly meaningful or representative wave period condition at this location.

1.4. Survey Results

1.4.1. This section provides a brief overview of the depth-averaged flow regime and summarises key findings from the static instrument package during each deployment period. An additional summary of the variation in 3D flow structure, throughout the water column, is also provided.

Period 1

1.4.2. Results of Period 1 (12 August 2022 – 01 October 2022) can be viewed within Annex A.

Current speed and direction

1.4.3. Depth-averaged current speed throughout Period 1 was consistently higher during spring tide phases (as compared to neaps), with peak values of *circa* 1.5 m/s (ebb tide) and *circa* 1.3 m/s (flood tide) respectively. During a neap tide phase, peak values were *circa* 0.8 m/s (ebb) and *circa* 0.4 m/s (flood).

1.4.4. Current speeds were also variable with depth throughout Period 1 depending on tidal state. Maximum speeds were seen during the later stages of spring ebb tides (HW + 4 hr to LW), where values exceeded 1.6 m/s in upper sections of the water column (i.e. between 10-17 metres above seabed (mAB), reducing to between 1.2 m/s and 0.8 m/s approaching the near seabed (i.e. between 1.5-4.0 mAB). Flood tides displayed similar vertical structure, albeit with smaller values between 1.4 m/s (upper) and 0.8 m/s (lower). Peak flood flows are also active for a smaller duration between HW – 2 hr and HW.

1.4.5. Current directions were generally aligned with the orientation of the estuary throughout a tidal cycle, remaining consistent throughout the duration of the flood with NNW flow (between 290°N and 295°N). During the ebb flows were also generally uniform, with initially ESE flows (*circa* 120°N) becoming more E (*circa* 100°N) approaching LW.

Wave climate

1.4.6. Wave heights throughout Period 1 were generally less than 0.8 m and showed a semi-diurnal relationship with water level (highest heights over HW periods and lowest heights around LW), indicating most were locally wind generated. A maximum wave height H_{max} of 1.19 m was observed on 03 September 2022, with an elongated period of higher wave heights between 16-18 September 2022 resulting from predominantly northerly wind conditions.

1.4.7. Peak wave period (T_p) generally remained between 2 s and 5 s, with mean wave period (T_z) between 1 s and 3 s. Similarly to wave height, a semi-diurnal relationship of wave period and water level can be established, indicating most waves are locally wind generated. Occasionally larger T_p between 6 s and 10 s were isolated values with little or no respective increase in T_z values. These are likely a result of vessel wake from commercial shipping approaching/exiting IOT and the Port of Immingham. Although these are correctly derived values by the

AWAC instrument, a large proportion have been flagged during the QA process and should be treated with caution.

1.4.8. Wave direction was generally variable, although with a slight bias from E and NE sectors between 45°N and 110°N which reflects the deployment location in relation to the estuary. Between 16-18 September 2022, waves were concentrated from a N direction (315°N-360°N). This period resulted in a small increase in wave heights above routine values.

Turbidity

1.4.9. Following recovery of the frame on 01 October 2022, data download was attempted from the RBR Duo TU/DO (SN: 52601). No data was retrieved on the logger, with a timestamp malfunction apparent from deployment on 12 August 2022. The instrument was re-programmed and tested onboard *UKD Seahorse* prior to re-deployment the following day for the data period 2.

1.4.10. No results are therefore presented for Period 1.

Period 2

1.4.11. Results of Period 2 (02 October 2022 - 14 November 2022) can be viewed within Annex A.

Current speed and direction

1.4.12. Patterns of current speed throughout Period 2 were similar to those during Period 1, with the highest values occurring during the spring phase with peak values of *circa* 1.4 m/s (ebb tide) and 1.2 m/s (flood tide). During a neap phase, peak values were between 0.8 m/s during the ebb and *circa* 0.7 m/s during the flood.

1.4.13. Current speed remained variable with depth throughout Period 2. During a spring phase, speeds on an ebb tide were around 1.6 m/s in upper sections of the water column (i.e. between 10-14 metres above seabed (mAB), reducing to between 0.8 m/s and 1.0 m/s approaching the near seabed (i.e. between 1.5-4.0 mAB). However, during a neap phase, overall lower flow speeds were also more uniform with depth, with similar overall speeds at the near surface to the near bed.

1.4.14. Current directions remain aligned with the orientation of the estuary throughout a tidal cycle, and are consistent throughout the duration of the flood with NNW flow (between 290°N and 295°N). During the ebb flows were also generally uniform, albeit with slightly more SE emphasis during stronger neap phases (*circa* 130°N to 100°N approaching LW).

Wave climate

1.4.15. Wave heights throughout Period 2 were generally less than 0.6 m. During calmer conditions, significant (H_s) and maximum (H_{max}) wave heights remained between 0.2 m and 0.5 m. A peak H_{max} of 1.49 m was observed on 19 October 2022, resulting from a 36-hour period of wind speeds concentrated from an E direction. Enhanced wave heights were also observed on 17 October 2022, between 02-03 November 2022 and 08 November 2022, most likely associated with enhanced wind speeds and/or waves propagating up (and across) the estuary.

1.4.16. Peak wave period (T_p) generally remained between 2 s and 5 s, with mean wave period (T_z) between 1 s and 3 s. A semi-diurnal relationship of wave period and water level can be established, indicating most waves are locally wind generated. Occasionally larger T_p of around 6 s are usually isolated values (with little or no respective increase in T_z values) and are likely a result of vessel wake from commercial shipping approaching/exiting IOT and the Port of Immingham. Although these are correctly derived values from the observed conditions, these have generally been flagged during the QA process and should be treated with caution.

1.4.17. Wave direction was generally variable, although with a slight bias from easterly sectors between 45°N and 135°N which reflects the deployment location in relation to the estuary. Between 19-21 October 2022, waves were concentrated from an E direction (80-110°N). This period coincided with generally larger wave heights.

Turbidity

1.4.18. Turbidity values during Period 2 generally ranged between 0-1400 NTU, with individual anomalies ranging up to 1900 NTU. Values peak and trough in phase with tidal conditions, with the lowest values over HW slack. Values then steadily increase throughout the ebb tide and peak shortly after LW, before falling throughout the flood tide to the subsequent HW. Slack water periods also show a variation of ±100 NTU depending on spring/neap tidal phase. A sustained period of lower Turbidity readings between 100 NTU and 400 NTU occurred on a neap tide phase between 18 October 2022 and 22 October 2022. This coincided with the period of sustained winds from easterly directions (*circa* 90°N).

Period 3

1.4.19. Results of Period 3 (14 November 2022 - 05 January 2023) can be viewed within Annex A.

Current speed and direction

1.4.20. Like previous periods, the highest values during Period 3 occurred during spring tide phases, where depth-averaged ebb tide/flood tide speeds are around 1.4 m/s and 1.0 m/s respectively. On a neap phase, speeds are reduced to less than 0.8 m/s (ebb) and 0.6 m/s (flood) respectively.

1.4.21. Current speed remained variable with depth throughout Period 3 with peak speeds in excess of 1.5 m/s in the top half of the water column (i.e. between 7-15 mAB) during a spring ebb tide, and around 1.0 m/s during a spring flood tide. These values then steadily decreased during the lower half of the water column approaching the seabed (0-7 mAB). On neap tide phases, higher flow speeds were generally restricted to the top 3 m of the water column during an ebb tide and were more uniform with depth on a flood tide.

1.4.22. Current direction remains aligned with the orientation of the estuary throughout a tidal cycle during both spring and neap phases; with NNW flow (between 290°N and 310°N) during the flood tide and SE flows (between 100°N and 125°N) during the ebb tide. However, in period 3, direction became slightly more variable over slack water periods during neap tide phases.

Wave climate

1.4.23. The wave climate seen throughout Period 3 was more variable than the previous data period, with a number of short-term (<5 hr) peaks in wave height (up to 1.9 m H_{max}) occurring in the first 10 days of the data period (14 November 2022 to 22 November 2022). A longer (*circa* 72-hour) period of enhanced wave heights was observed between 03 December and 06 December 2022, resulting from a sustained period of NE and E wind conditions. Outside of these events, the majority of significant wave heights throughout the record remained similar to Period 2, with heights between 0.2 m and 0.8 m. Wave periods also remained similar with the majority of T_p values between 2 s and 5 s and occasional short-term peaks above 5 s.

1.4.24. Wave direction remains variable, although a greater concentration of waves from easterly sectors are apparent. These generally resulted in either a) larger wave heights, or b) larger, more defined peak period signal (T_p) against background mean wave periods (T_z).

Turbidity

1.4.25. Turbidity during Period 3 was generally similar to previous periods, with values ranging between 0-1,300 NTU. Values show fluctuation coherent with tidal cycle, with maximum values occurring from mid-flood tide level to HW slack and between HW slack and mid-ebb level. During low water slack, minimum values on a neap phase are between 100-200 NTU and between 300-600 NTU on a spring phase.

Period 4

1.4.26. Results of Period 4 (06 January 2023 - 03 March 2023) can be viewed within Annex A.

Current speed and direction

1.4.27. Current speeds throughout Period 4 were generally the highest of all deployment periods, reflecting the larger spring tide ranges. Depth-averaged values during spring ebb tide on 23 January 2023 reached a maximum of 1.56 m/s, with peak ebb values also exceeding 1.5 m/s on the following spring tide phase around 21 February 2023. Flood tide speeds were around 1.2 m/s during these times. During neap tide phases, peak values lowered to around 0.8 m/s (ebb) and 0.4 m/s (flood).

1.4.28. During the larger spring tide ranges, maximum localised current speeds in excess of 1.6 m/s were widespread within mid and upper sections of the water column (i.e. between 7-14 mAB), with values above 1.4 m/s maintained through to the near seabed (<4 mAB) on occasional individual tides. During neap tide phases, peak ebb speeds of *circa* 1.0 m/s were apparent within the near-surface and upper water column (i.e. between 10-15 mAB), reducing to 0.8 m/s near the seabed. Values throughout the water column during a flood tide on neap phases were generally less than 0.6 m/s.

1.4.29. Current direction remains aligned with the orientation of the estuary throughout a tidal cycle during both spring and neap phases; with NNW flow (between 295°N and 305°N) during the flood tide and SE flows (initiating at 130°N and reducing to around 100°N) during the ebb tide.

Wave climate

1.4.30. Wave climate during Period 4 was more benign than the previous period. Significant wave heights throughout the record generally remained below 0.8 m, and for much of the record remained below 0.4 m. Peak H_{max} values were approximately 1.3 m which were observed during a sudden increase and change to N wind speeds on 16 January 2023. Wave periods generally remained under 6 s with occasional individual spikes in T_p above this value likely to be associated with ship wake. Both H_{max} and H_{m0} were also slightly elevated between 24 February 2023 and 26 February 2023 due to a sustained period of elevated wind speed.

1.4.31. Wave direction reverted to being more E-SE (100-135°N) during Period 4, with short (circa 72-hour) durations where waves were focussed from northerly directions (315-360°N). This was apparent between 30 January 2023 to 04 February 2023 (which also resulted in increased wave heights) and 17 February 2023 to 20 February 2023.

Turbidity

1.4.32. Turbidity during Period 4 was generally similar to the previous data period. The vast majority of values ranged between 100-1400 NTU, with greater variability over the tidal cycle during spring tide phases than neap tide phases (and similar semi-diurnal patterns over peak flow and slack water periods). Short-term increases in Turbidity above the expected signal are apparent during neap tide phases on 02 February 2023 and 16 February 2023. These are likely to result from either temporary snagging of debris/weed on the seabed frame, or deposition of dredge spoil East of the Port of Immingham.

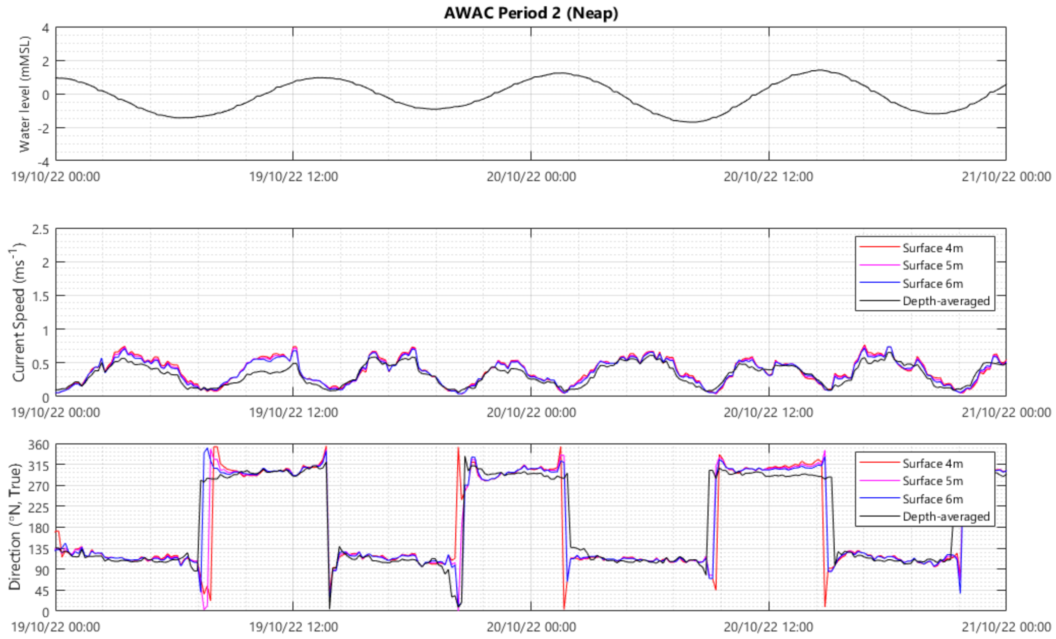
3-D flow variation

1.4.33. To provide consistency with previous analysis of hydrodynamic data in the vicinity of the AWAC deployment location, further data processing steps were also conducted on this latest series of deployments and have been provided with the data deliverables for each Period.

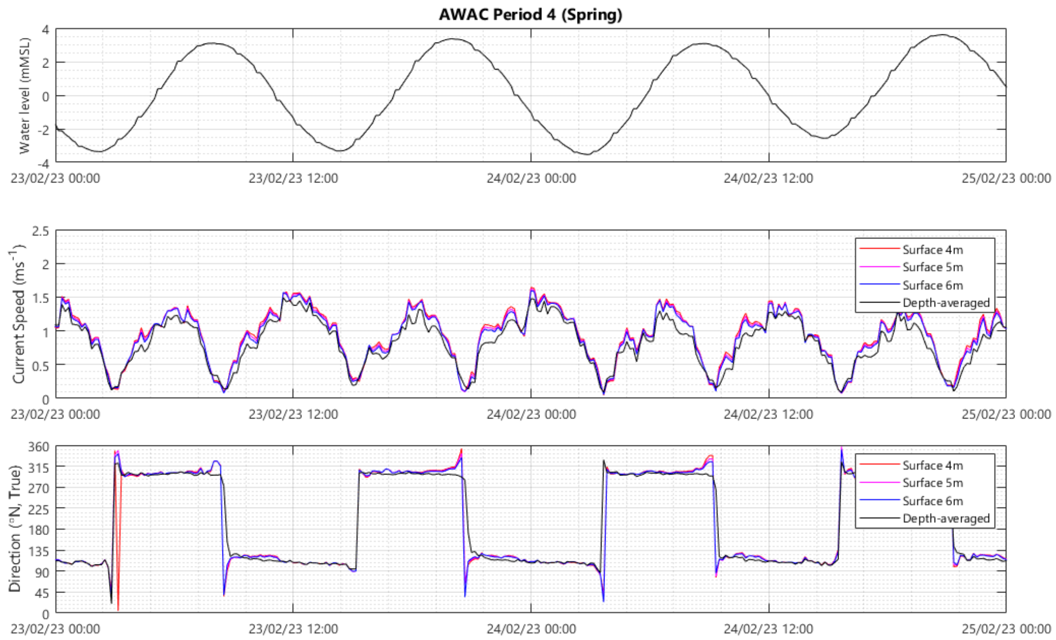
1.4.34. Near-surface current speed and direction per 0.5 m depth cell was then averaged for the additional required depth ranges based on expected vessel drafts of 5 m, 6 m and 7 m.

1.4.35. The AWAC processing procedure involves the removal of data from the top 10% of the water column to remove the effects of any surface turbulence. During the 6-month deployment water column thickness ranged from 10.6 m - 17.6 m and therefore the top 1-2 m (dependant on tide) of water is removed from the final dataset. For this reason, averaging data for the upper 4 m of valid data is approximately equivalent to averaging data in the upper 5 m of water column. Consequently, data has been processed for the upper 4 m, 5 m and 6 m of valid data, which can be assumed the equivalent of the upper 5 m, 6 m and 7 m, respectively, of water column. Examples of the timeseries outputs, comparing the original depth-averaged data against the upper water column averages (upper

4 m, 5 m and 6 m of valid data) over a neap and a spring tide, are provided in Plate 1-3.



Example 1: Neap tide - data Period 2 (19 October 2022 to 21 October 2022)



Example 2: Spring tide - data Period 4 (23 February 2023 to 25 February 2023)

Plate 1-3. Example variation in current speed and current direction between surface layers and depth-averaged values

1.4.36. A summary of the data suggests:

- Near-surface speeds remain generally higher than the depth averaged values during flood and ebb tides, with a maximum difference of *circa* 0.3 m/s;
- Depth-averaged flows after LW can initiate flood (NW) directions earlier than near-surface flows;
- Near-surface current flows following HW can initiate ebb (SE) directions earlier than the depth-averaged flows;
- Current directions during later stages of a neap flood tide are orientated up to 20° further towards North (*circa* 305°T) than the depth-averaged flows (*circa* 290°T). However, negligible difference is seen on a spring tide; and
- Negligible difference in direction was determined between ebb tide current directions at the near-surface compared to the depth-average. This was the case on both spring and neap tide phases.

Additional notes

Weather conditions

1.4.37. Weather conditions throughout various vessel activities were as below:

- 12 August 2022 - Winds variable F0-1. Sea state calm/smooth. Visibility moderate/good;
- 01 October 2022 - Winds W F4-5. Sea state slight. Visibility good;
- 02 October 2022 - Winds W F2. Sea state smooth/slight. Visibility good;
- 14 November 2022 – Winds S F1-2. Sea state smooth. Visibility moderate, occ. poor;
- 05 January 2023 – Winds SW F3. Sea state slight. Visibility good/moderate;
- 06 January 2023 – Winds SW F3. Sea state smooth/slight. Visibility moderate; and
- 03 March 2023 – Winds NE F2. Sea state slight. Visibility good/moderate.

1.5. Data Deliverables

1.5.1. **Table 1-2** provides details of the processed data deliverables that accompany the survey report.

Table 1-2. Data deliverables

Deliverable	Description	File Format
AWAC Currents	Times series provided for each deployment period: • Water level, current speed and current direction (depth-averaged, Upper valid 4 m, Upper valid 5 m, Upper valid 6 m) relative to True North at 10-minute intervals. at 10-minute intervals.	.xlsx
	Graphical plot provided for each deployment period: • Panel 1 - Water level • Panel 2 - Current speed through water column • Panel 3 - Depth averaged current speed • Panel 4 - Depth averaged current direction	.png
AWAC Waves	Time series provided for each deployment period: • Significant wave height (H_{m0}), maximum wave height (H_{max}), peak wave period (T_p), mean wave period (Tz) and wave direction at hourly intervals.	.xlsx
	• Graphical plot provided for each deployment period: • Panel 1 - Water level • Panel 2 - Significant wave height (H_{m0}) and Maximum wave height (H_{max}) • Panel 3 - Peak wave period (T_p) and mean wave period (T_z) • Panel 4 - Peak wave direction ($DirTp$) and mean wave direction ($MeanDir$) • Panel 5 - Wind speed (Immingham weather station) • Panel 6 - Wind direction (Immingham weather station)	.png
Water Quality	Times series provided for each deployment period: • Turbidity at 10-minute intervals.	.xlsx
	Graphical plot provided for each deployment interval: • Panel 1 - Water level • Panel 2 - Wind speed (Immingham weather station) • Panel 3 - Wind direction (Immingham weather station) • Panel 4 - Turbidity	.png

1.6. References

Ref 1-1 National Oceanic and Atmospheric Administration (NOAA) Magnetic Field Calculators: https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml

1.7. Abbreviations/Acronyms

3D	Three Dimension(al)
ABP	Associated British Ports
ABPmer	ABP Marine Environmental Research Ltd
AWAC	Acoustic Wave and Current
CTD	Conductivity, Temperature, Depth
DirTp	Peak Wave Direction
DO	Dissolved Oxygen
GMT	Greenwich Mean Time
Hm0	Significant Wave Height
Hmax	Maximum Wave Height
Hs	Significant Wave Height
HW	High Water
Hz	Hertz
IOT	Immingham Oil Terminal
LW	Low Water
mAB	metres Above Seabed
MeanDir	Mean Wave Direction
MHz	Megahertz
MSL	Mean Sea Level
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric Turbidity Units
OBS	Optical Backscatter

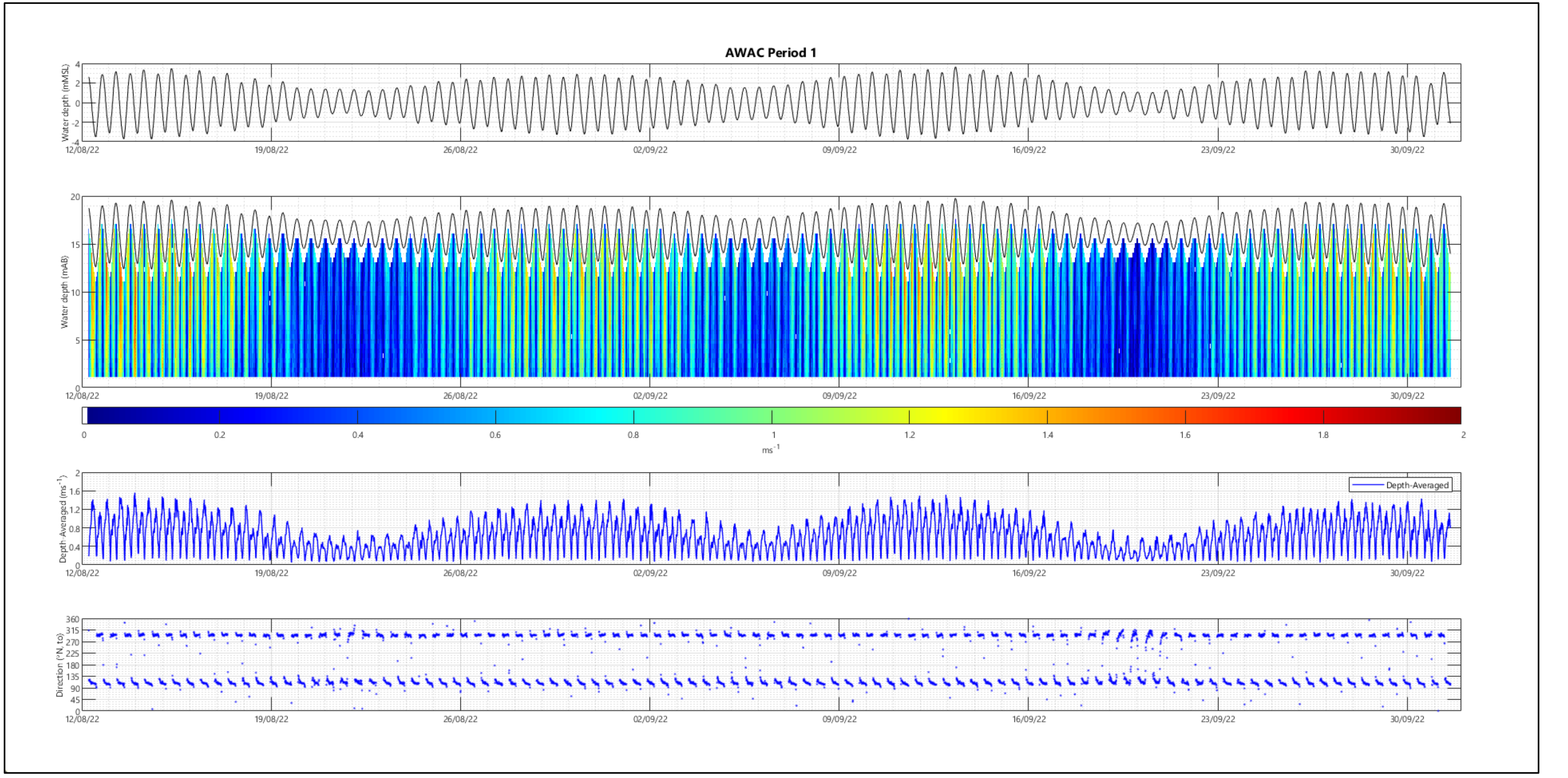
OSGB36	Ordnance Survey Great Britain 1936
OSTN15	Ordnance Survey Transformation Model 2015
png	Portable Network Graphic
QA	Quality Assurance
RA	Risk Assessment
SN	Serial Number
SSOW	Safe Systems of Work
Tp	Peak Wave Period
TU	Turbidity
Tz	Mean Wave Period
UKD	UK Dredging
WGS84	World Geodetic System 1984
xlsx	Microsoft Excel open spreadsheet

Cardinal points/directions are used unless otherwise stated.

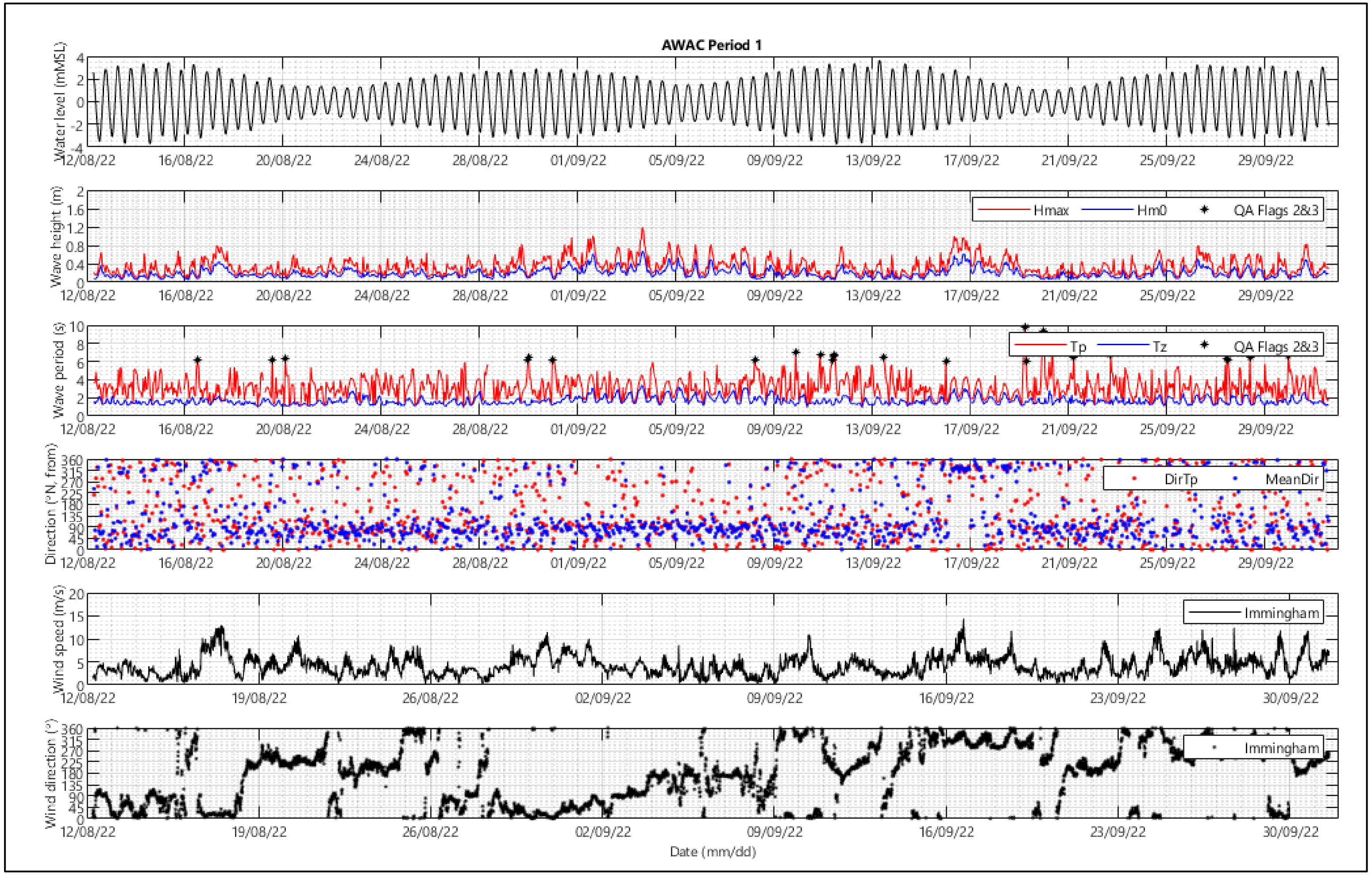
SI units are used unless otherwise stated.

Annex A Period Results

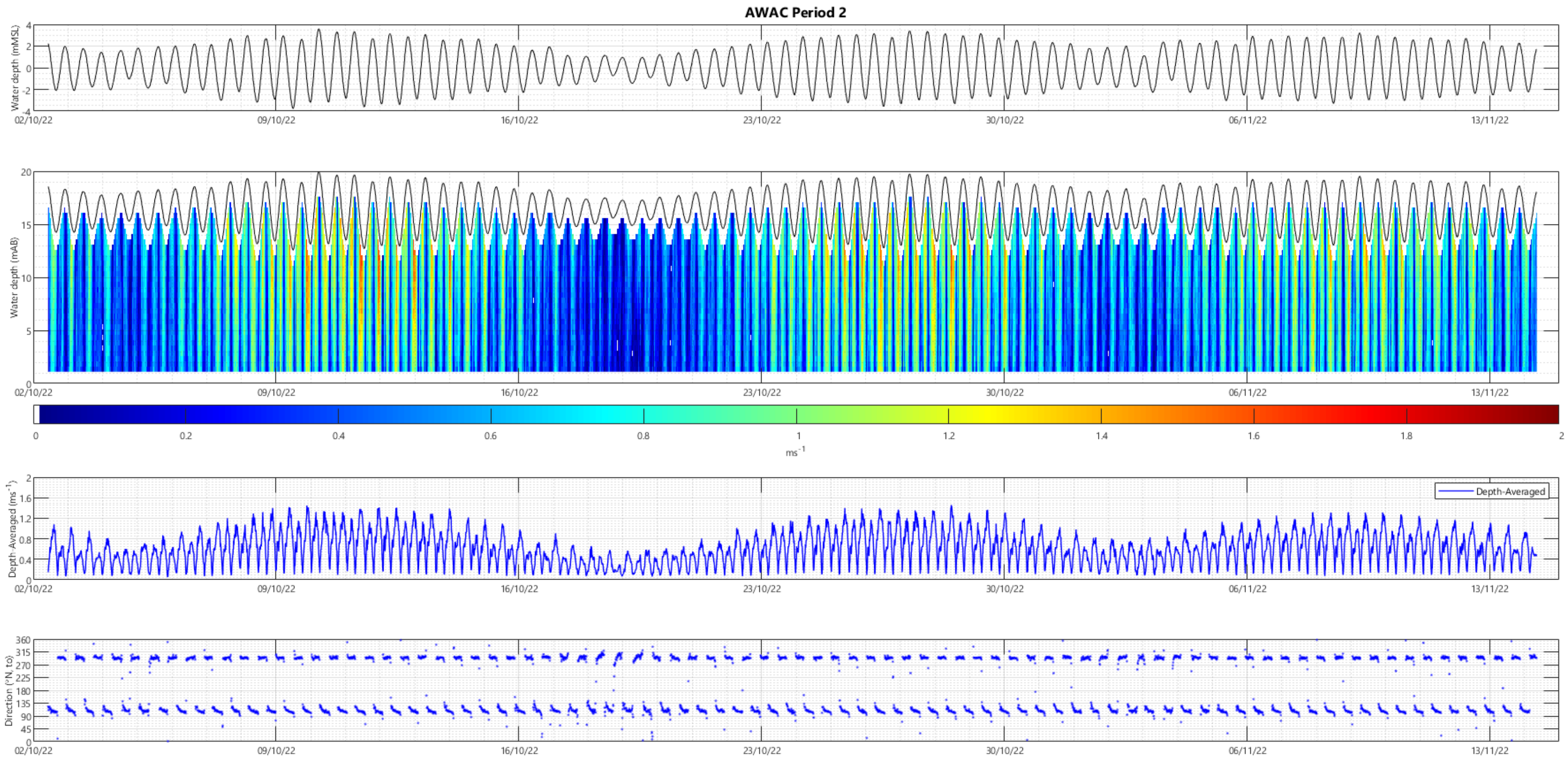
Period 1 - Current Speed and Direction



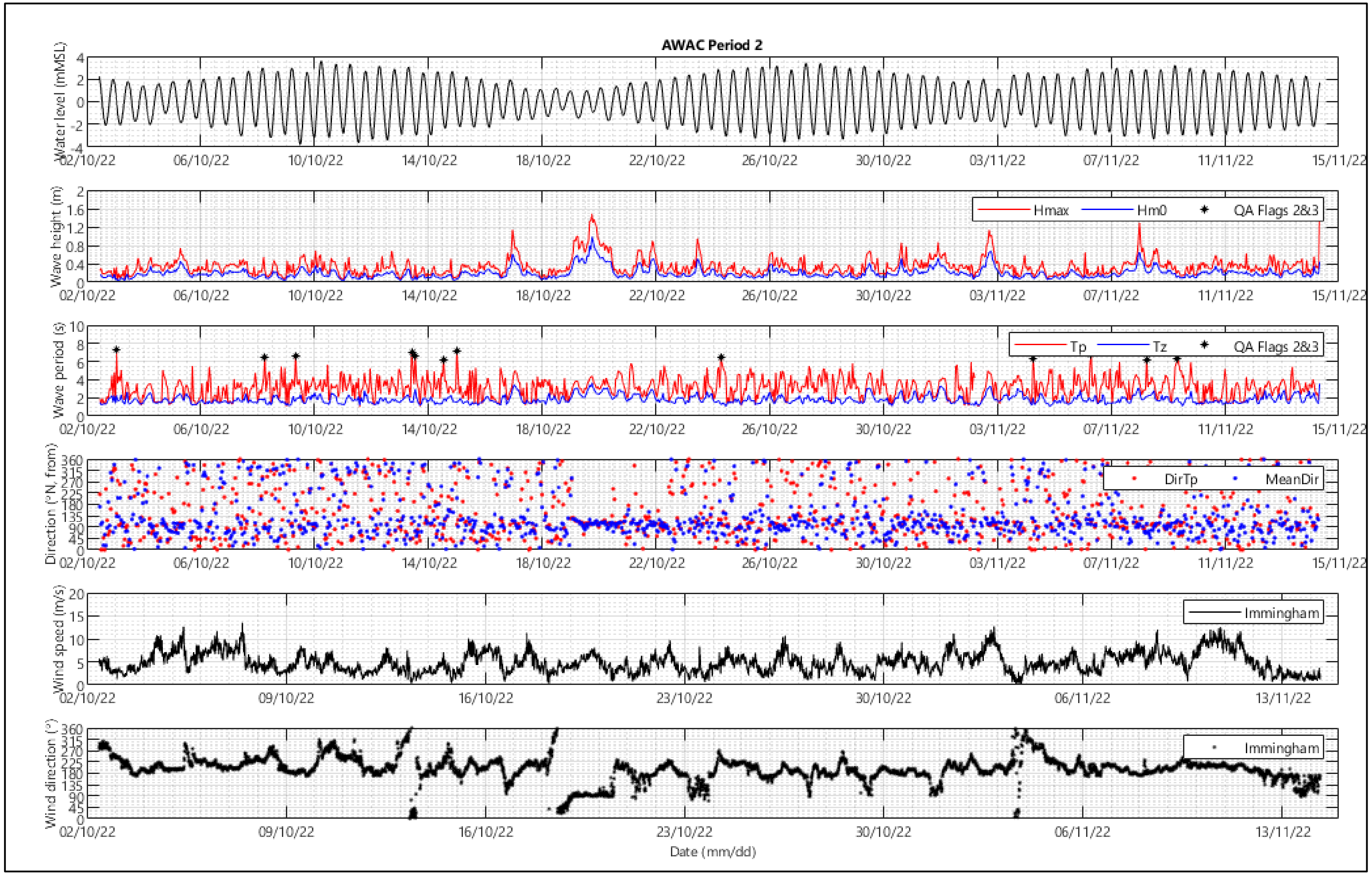
Period 1 - Wave Parameters



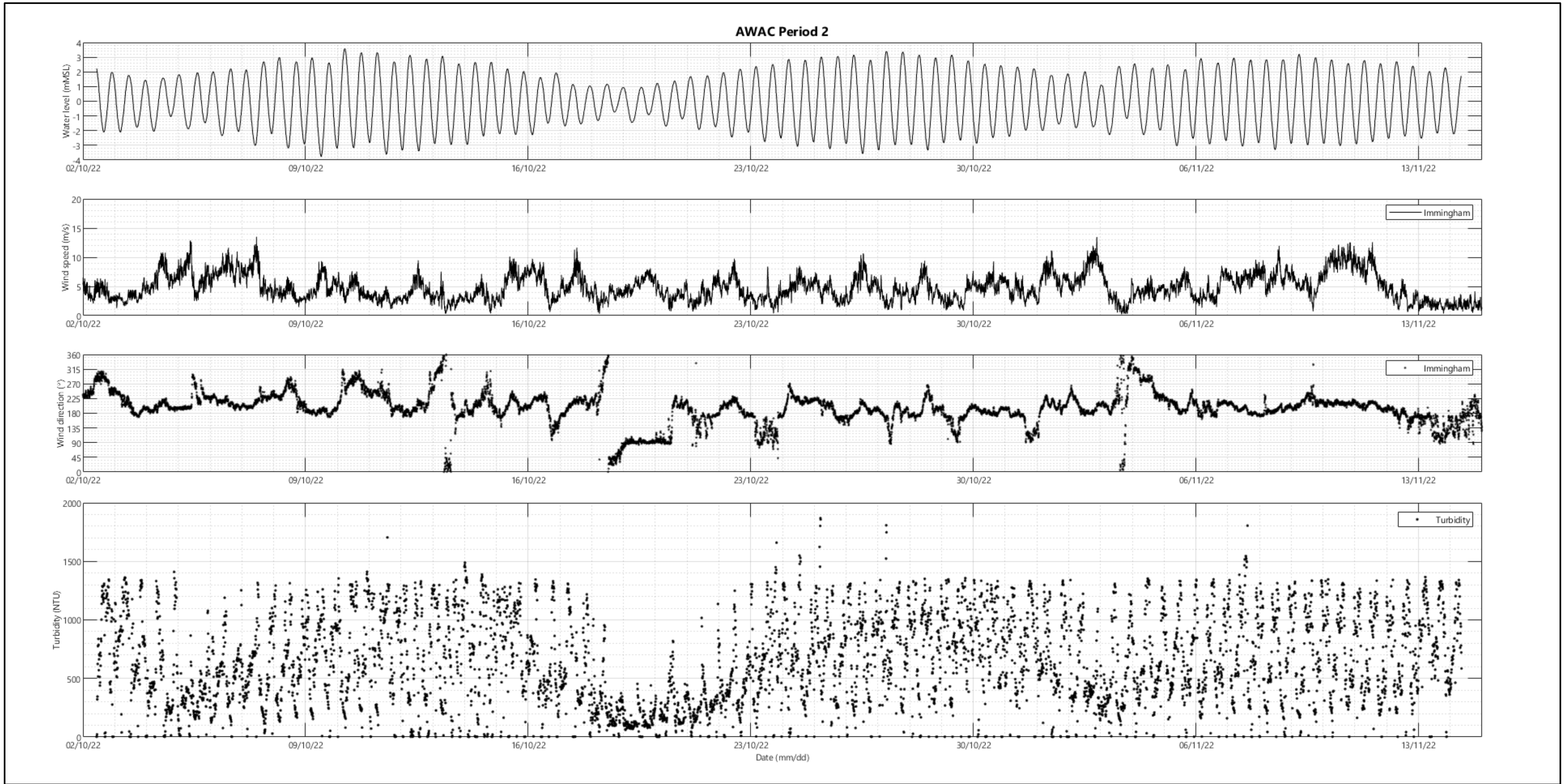
Period 2 - Current Speed and Direction



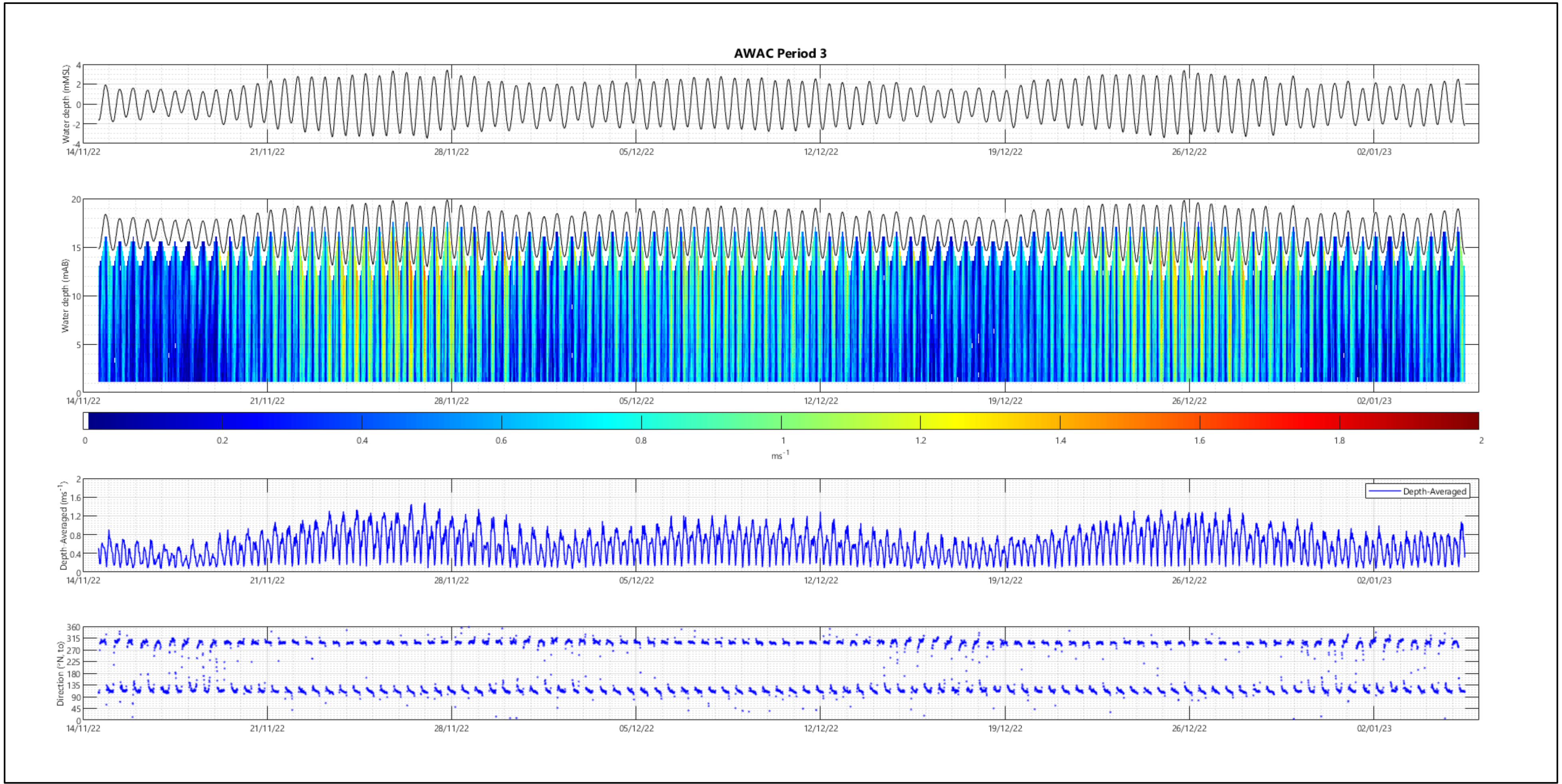
Period 2 - Wave Parameters



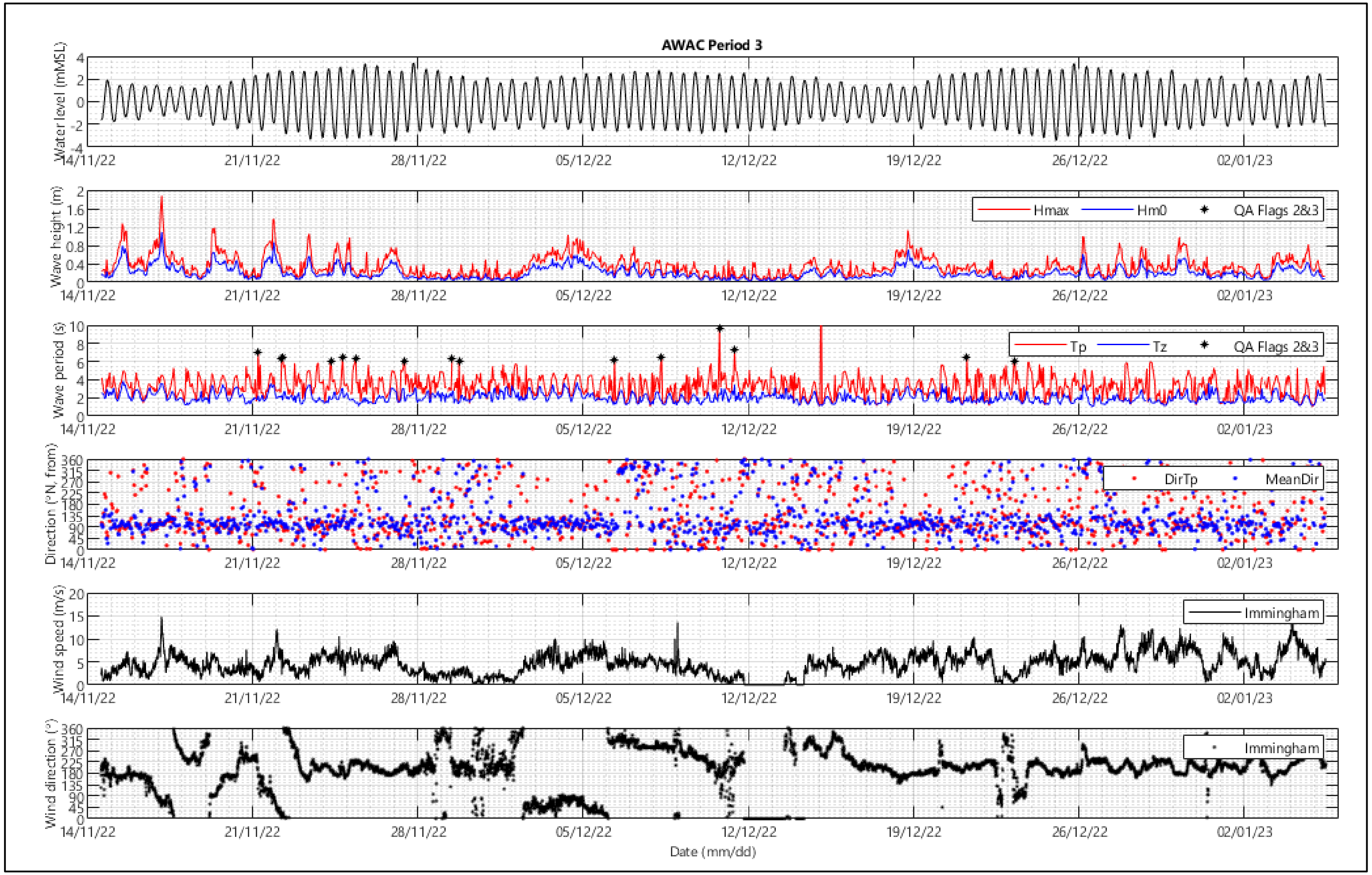
Period 2 - Turbidity



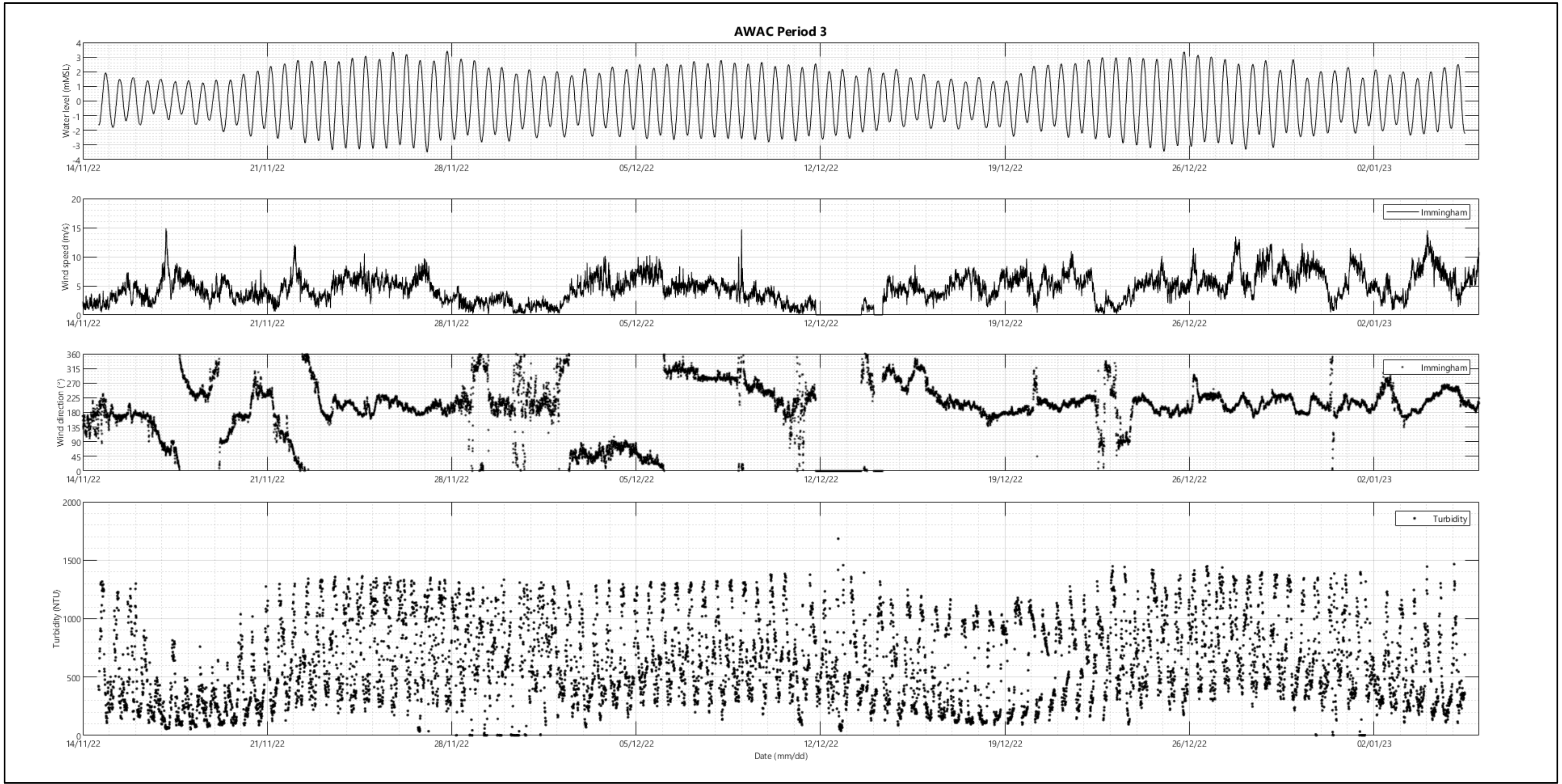
Period 3 - Current Speed and Direction



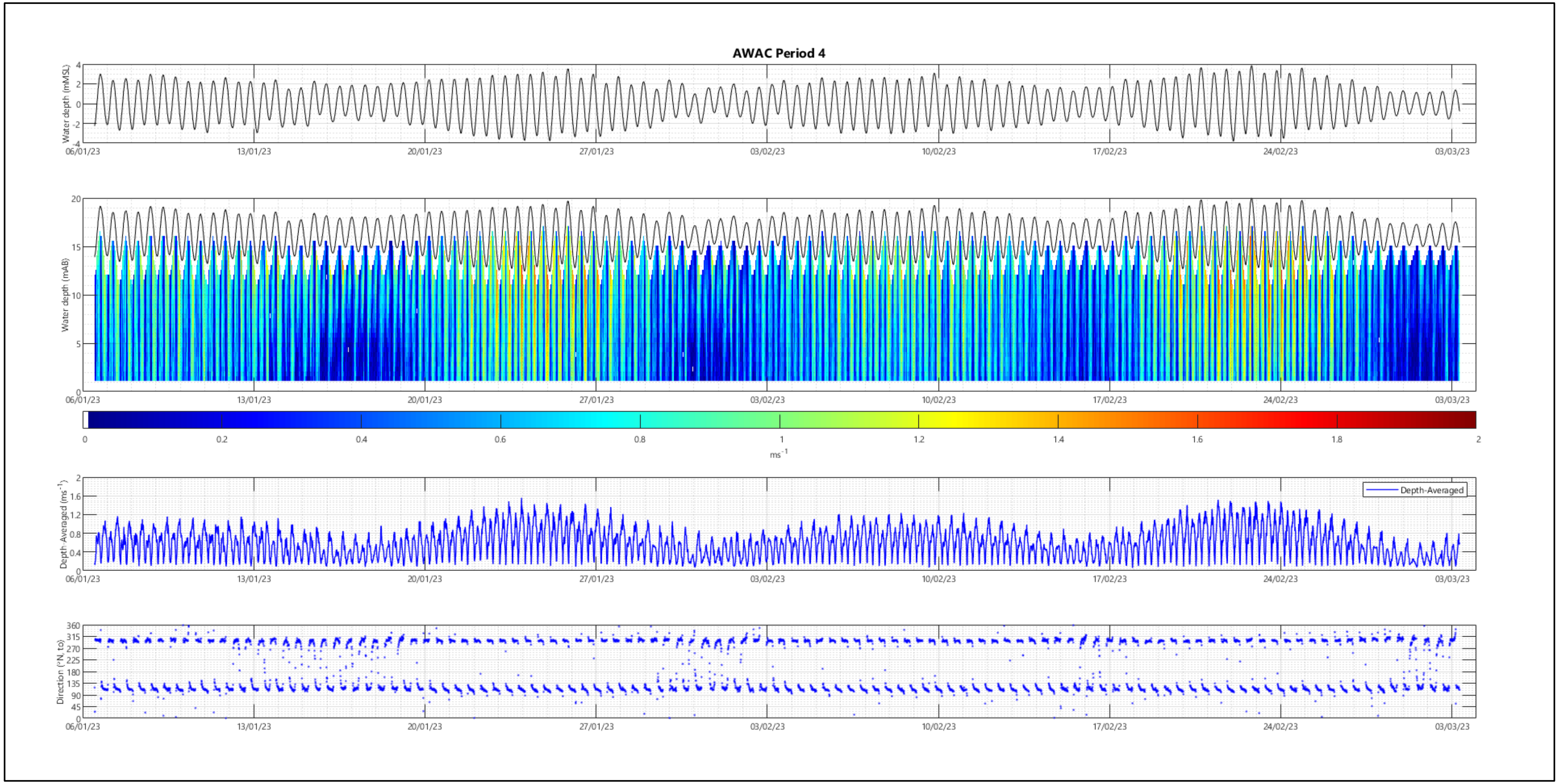
Period 3 - Wave Parameters



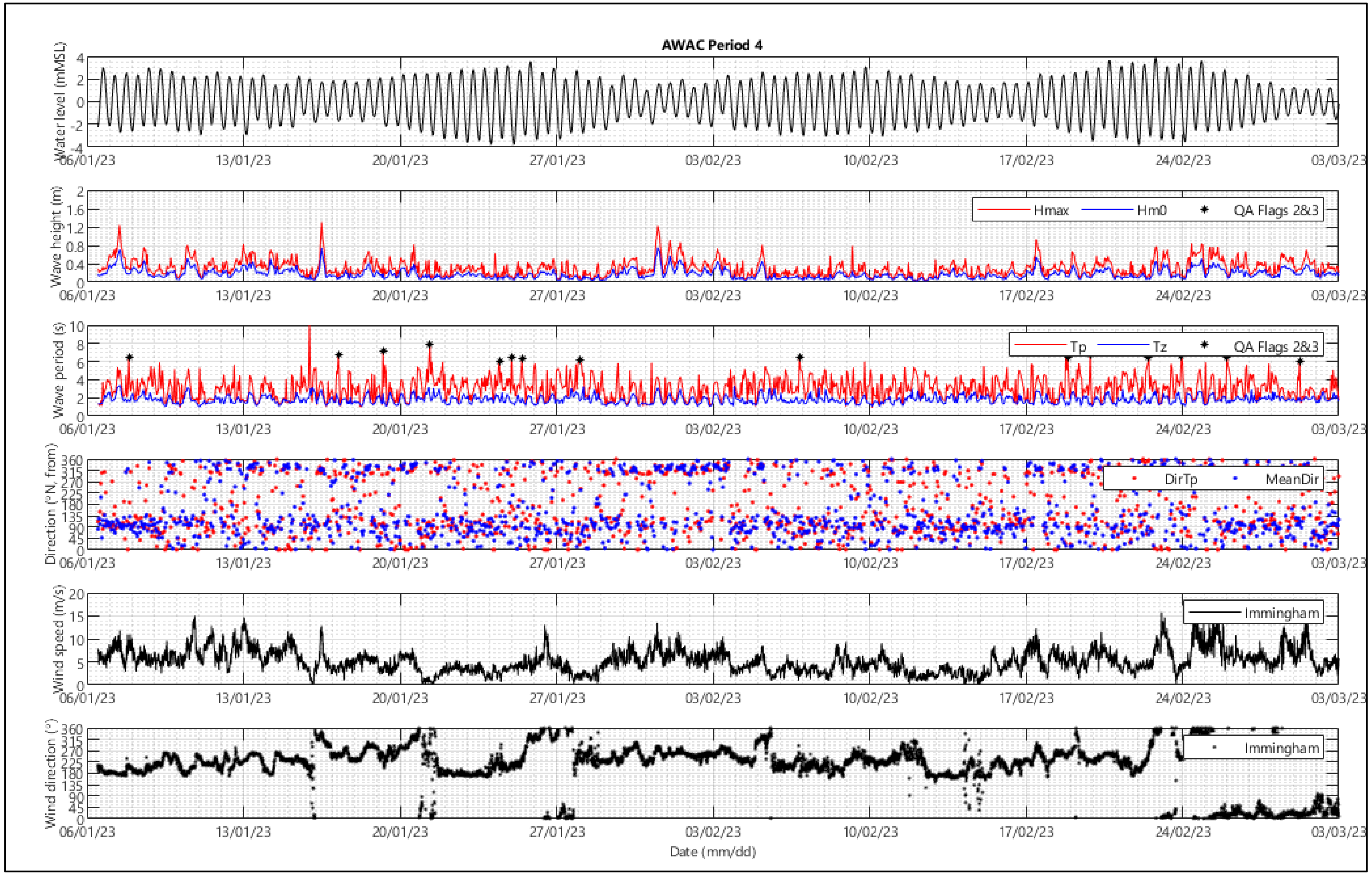
Period 3 - Turbidity



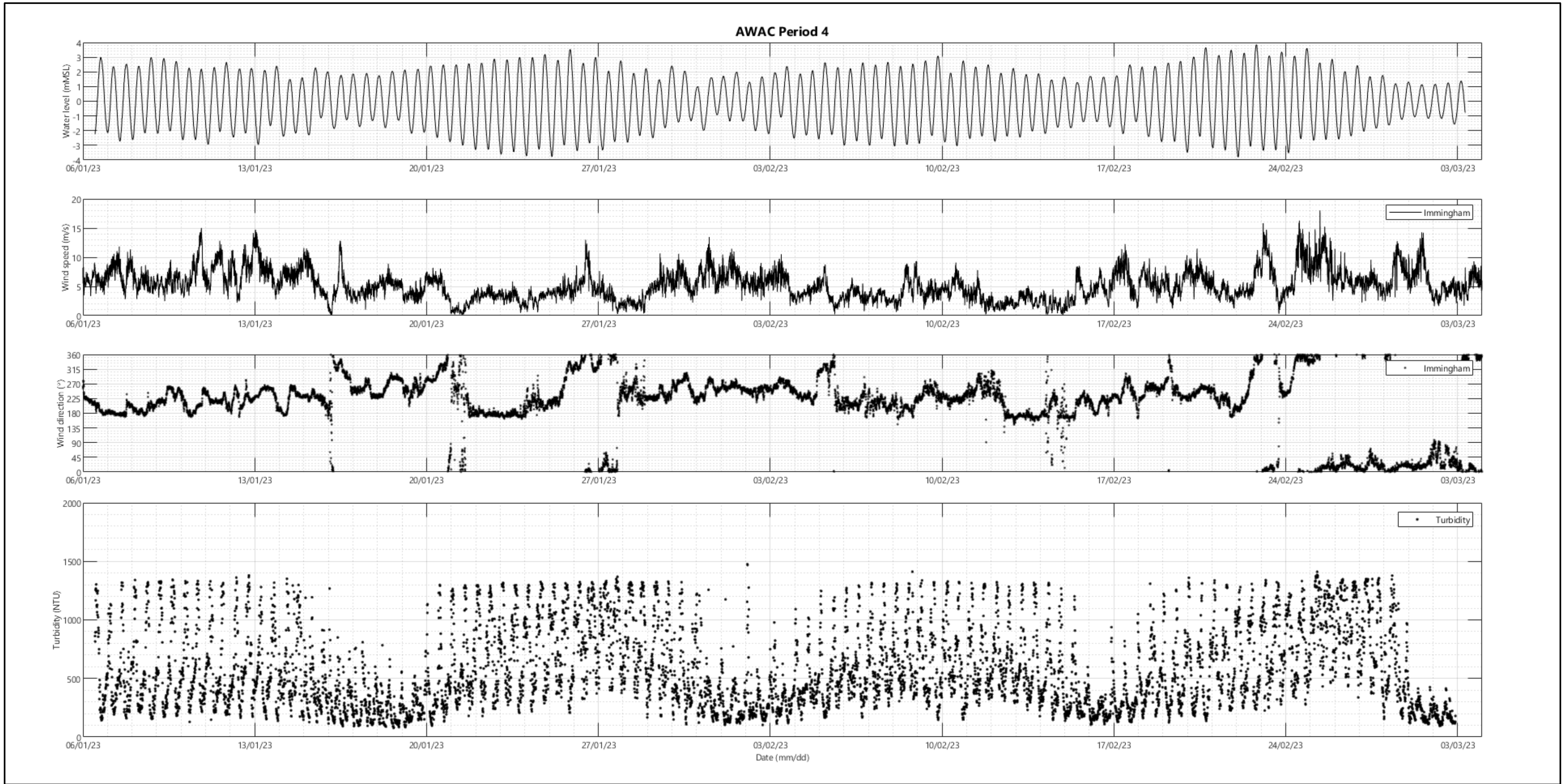
Period 4 - Current Speed and Direction



Period 4 - Wave Parameters



Period 4 - Turbidity



Annex B Equipment Specifications

1. Nortek AWAC
2. RBR duo

ACOUSTIC WAVE AND CURRENT PROFILER

AWAC - 1 MHz

NORTEK

Real-time current profiles and directional waves for shallow water

The AWAC 1 MHz ADCP has become the standard reference technology in submerged wave-measurement applications. Thousands of these ADCPs have been deployed to capture the full wave spectrum in combination with current profiles. With a 35 m maximum range for wave measurements and 4 Hz sampling of the surface elevation, the AWAC 1 MHz is the optimal tool for shallow current and wave measurements.

ACOUSTIC WAVE AND CURRENT PROFILER

AWAC - 1 MHz

Highlights

- Real-time current profiles to 30 m range
- Real-time directional waves to 35 m range
- Acoustic surface tracking (AST) with vertical beam
- Can be used both with fixed frames and subsurface buoys

Applications

- Online measurements of currents and waves
- Design data for planning of new coastal structures
- Site studies for offshore wind platforms
- Coastal erosion studies
- Measurement campaigns where the full wave spectrum is needed
- Monitoring of transient waves for channel wall protection
- Studies of tidal currents

ACOUSTIC WAVE AND CURRENT PROFILER

AWAC - 1 MHz

NORTEK

Technical specifications

→ Water velocity measurements	
Maximum profiling range	30 m
Cell size	0.25-4.0 m
Number of cells	Typical 20-40, max. 128
Velocity range	±10 m/s horizontal, ±5 m/s along beam
Accuracy	±1% of measured value ±0.5 cm/s
Velocity precision	Consult instrument software
Maximum output rate	1 Hz
Internal sampling rate	7 Hz
→ Echo intensity (along slanted beams)	
Sampling	Same as velocity
Resolution	0.45 dB
Dynamic range	90 dB
Transducer acoustic frequency	1 MHz
Number of beams	3 beams 120° apart, one vertical beam (90° apart, one at 5° for platform mount)
Beam width	1.7°
Beam width vertical beam	1.7°
→ Wave measurement option (AST)	
Maximum depth	35 m
Data types	Pressure, one velocity along each beam, AST
Sampling rate velocity (output)	2 Hz
Sampling rate AST (output)	4 Hz
No. of samples per burst	512, 1024 or 2048

RBR

MEASURE THE BLUE PLANET

rbr-global.com

RBR*duo*^{3}

TWO CHANNEL RECORDER

MEASURE MORE,
DEPLOY LONGER,
DOWNLOAD
FASTER

RBR*duo*^{3} dual channel loggers offer flexible measurement schedules, standard sampling up to 2Hz, optionally up to 32Hz, large memory, extra power for extended deployments, twist activation, and USB-C download for large data files.

FEATURES

- Wi-Fi ready
- Twist activation
- 240M readings
- Up to 32Hz sampling
- USB-C download
- Realtime communications

The RBR*duo*^{3} is a dual channel logger available many configurations. Examples:

▶ RBR*duo*^{3} T.D	measures temperature and depth
▶ RBR*duo*^{3} T.DO	measures temperature and dissolved oxygen
▶ RBR*duo*^{3} C.T	measures conductivity and temperature (salinity)

*For additional information on tide and wave recorders, please see the Tide and Wave data sheet.

Additionally, the RBR*duo*^{3} can be fitted with any two sensors:

- Temperature
- Depth
- Conductivity
- Tide
- Wave
- Dissolved O_2
- Turbidity
- Fluorescence
- T-string
- pH
- ORP (RedOx)
- PAR

TWO CHANNEL RECORDER

MEASURE MORE, DEPLOY LONGER, DOWNLOAD FASTER

The RBR*duo*³ makes it easy to configure the optimum sampling regime for your measurements. The large data storage capacity and fast download ability facilitate long deployments with higher sampling rates. Almost every sensor from RBR can be interfaced to the RBR*duo*³. Dataset export to Matlab, Excel, OceanDataView®, or text files makes post processing with your own algorithms effortless.

Specifications

Physical

Storage:	240M readings
Power:	8 AA cells
Communication:	USB-C or RS-232/485
Clock drift:	±60 seconds/year
Depth rating:	750m (plastic), 10,000m (titanium)
Housing:	Plastic or titanium
Size:	~340mm x Ø63.25mm without sensors
Weight:	Configuration dependent
Sampling rate:	24hr to 1s and 2, 4, 8, 16, 24, or 32Hz
Averaging rate:	>1s, 2, 4, 8, 16, 24, or 32Hz
Averaging duration:	1s to 24h

Conductivity (up to 6000m)

Range:	0-85mS/cm
Initial accuracy:	±0.003 mS/cm
Resolution:	0.001 mS/cm
Typical stability:	0.010 mS/cm per year

Temperature

Range:	-5°C to 35°C
Initial accuracy:	±0.002°
Resolution:	0.00005°C
Time constant:	~1s (standard), ~0.1s (option)
Typical stability:	0.002°C per year

Depth

Range:	20 / 50 / 100 / 200 / 500 / 750 1000 / 2000 / 4000 / 6000 10,000m (dbar)
Initial accuracy:	±0.05% FS (full scale)
Resolution:	0.001% FS
Time constant:	<0.01s
Typical stability:	0.1% FS per year

Dissolved Oxygen (OxyGuard®)

Range:	0 to 600%
Accuracy:	±2% O_2 saturation (5°C to 25°C)
Resolution:	1% of saturation
Response time:	~10s, 90% step change @ 20°C

Options

- Wi-Fi communication
- |fast8, |fast16 or |fast32Hz sampling for profiling
- External data and power connector with USB, RS-232, or RS-485

RBR Ltd

95 Hines Road
Ottawa, Ontario
Canada K2K 2M5

+1 613 599 8900
info@rbr-global.com
rbr-global.com

Annex C Equipment Calibration Certificates

OSIL
Environmental Instruments and Systems

Certificate of Calibration

Customer Details:			Certificate Number:
ABPMer Quayside Suite, Medina Chambers Town Quay, Southampton SO14 2AQ			*52601-44574*
OSIL Ref:	**615726**	**Customer P/O:**	**4600007857**

Instrument Details:			
RBR	**Duo DO.Tu**	**Serial No:**	**52601**

New Calibration Coefficients:

Parameter	A	B	C	D
Conductivity	n/a	n/a	n/a	n/a
Temperature	n/a	n/a	n/a	n/a
Pressure	n/a	n/a	n/a	n/a
pH	n/a	n/a	n/a	n/a
DO	-7.7418748007E+00	3.3888840846E+02	n/a	n/a
Turbidity	3.3090802228E+03	-4.5136977441E+03	n/a	n/a

Approval Signature:

Checked:

Date: *13/01/2022*

Calibration Details on the following sheets:

~~52601 Conductivity~~
~~52601 Temperature~~
~~52601 Pressure~~
~~52601 pH~~
52601 DO
52601 Turbidity

Next Calibration Due: 13/01/2023

OSIL Culkin House
Endeavour Business Park
Penner Road, Havant
Hampshire, PO9 1QN

t: +44(0)2392 488240
e: osil@osil.com
w: www.osil.com

Registered Number: 2351541
Registered Office: As opposite

RBR Duo DO.Tu Conductivity Calibration

CUSTOMER	**ABPMer**
SERIAL NUMBER	**52601**

Number of data pairs	4
Degree of fit	1
Standard	Turbidity Standards

Date	January 13, 2022
Barometric Pressure	1041.75 mBar
Ambient temperature	20.1°C

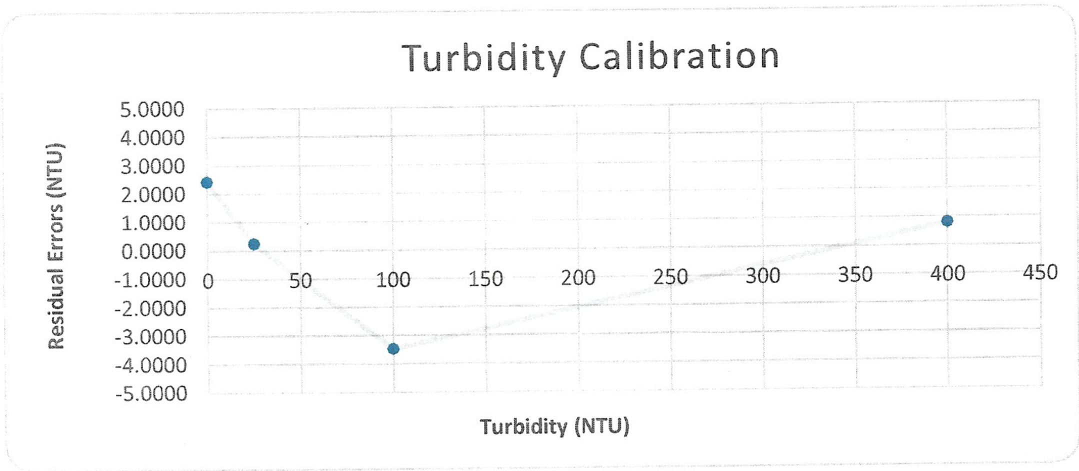
Polynomial Coefficients

Turbidity (NTU) = C0 + C1*Counts

Term	Coefficient
C0	3.3090802228E+03
C1	-4.5136977441E+03

polfit data

Standard Turbidity NTU	Instrument Counts	Calibrated Turbidity NTU	Residual Error Turbidity NTU
0.0000	0.7325827344	2.4232	2.4232
25.0000	0.7275275901	25.2406	0.2406
100.0000	0.7117334811	96.5304	-3.4696
400.0000	0.6443219220	400.8058	0.8058



RBR Duo DO.Tu Conductivity Calibration

CUSTOMER	**ABPMer**
SERIAL NUMBER	**52601**

Number of data pairs	2
Degree of fit	1
Standard	Oxygenated Water
	Sodium Sulphite
Date	December 20, 2021
Barometric Pressure	1026.6 mBar
Ambient temperature	20.1°C

Polynomial Coefficients

DO (% Sat) = C0 + C1*Counts

Term	Coefficient
C0	-7.7418748007E+00
C1	3.3888840846E+02

polfit data

Standard % Sat	Instrument Counts	Calibrated umol/L	Residual Error umol/L
100.4100	0.3191371322	100.4100	0.0000
0.4100	0.0240547466	0.4100	0.0000