SCOTTISH SEA FARMS LTD.

TOYNESS, SCAPA FLOW

CAR/L/1015855

MODELLING DATA COLLECTION REPORT

Report To	Scottish Environment Protection Agency
Deployment IDs	TOYNS, Toyness
Status	V1
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Contents

1 Introduction

This report presents the survey work undertaken by Scottish Sea Farms Ltd. at the existing Toyness fish farm located in Scapa Flow, Orkney (CAR/L/1015855). Two current meter deployments during 2018 are reported which have been conducted to collect the hydrographic data used to assess the proposed expansion at Toyness. Data collection and analysis follow guidance from the Scottish Environment Protection Agency (SEPA) (SEPA 2019a, SEPA 2019b, SEPA 2022).

2 Site description

The survey area is located adjacent to the existing fish farm on the northern shoreline of Scapa Flow, positioned approximately 440 m from the shore (Figure 2.1). This location is at the transition between a tidal dominated flow regime to the west and wind driven flow found on the eastern side of the Flow. The site is exposed to a moderate fetch from NE through SW. Depth at survey area is relatively uniform at around 30-35m where the seabed gradually shoals to the north before rapidly shelving from 20m quite close to the shore.

The proposed expansion at Toyness includes a relocation of the site centre 127m SW. Details of the existing and proposed infrastructure are found in Table 2.1.

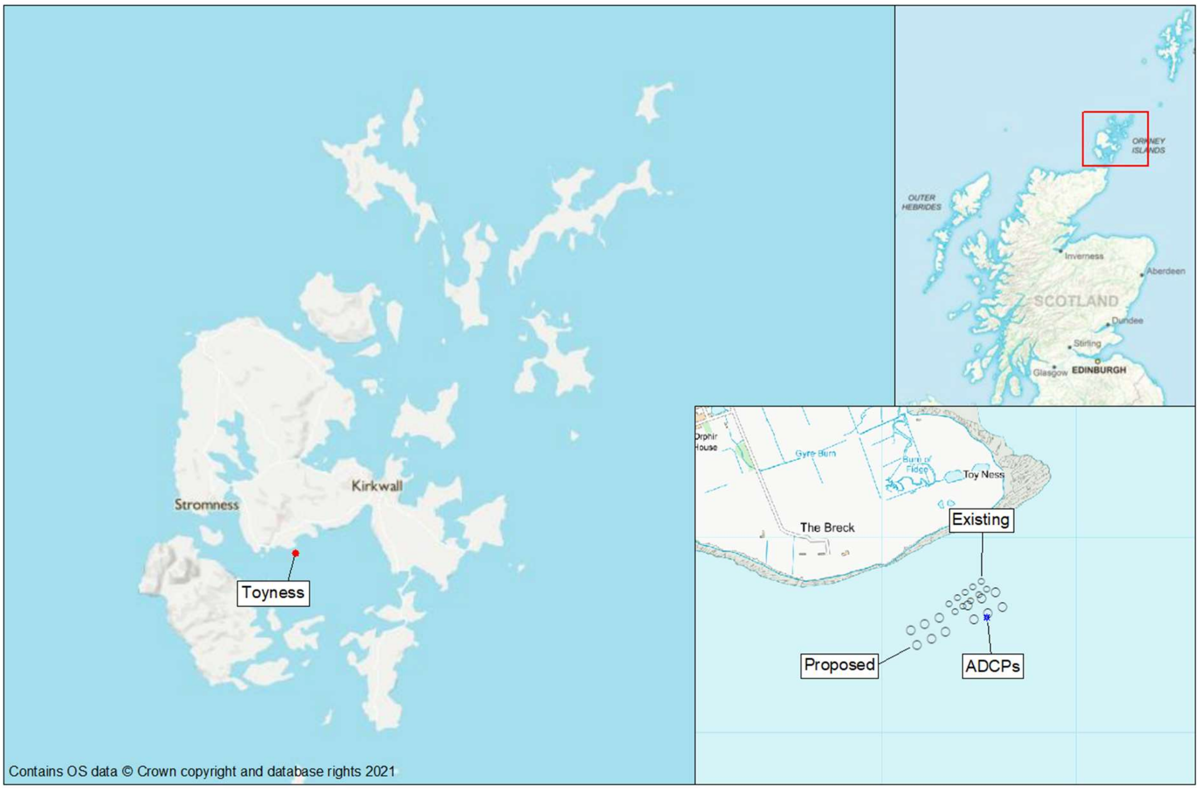


Figure 2.1 Location of the Toyness marine fish farm, existing and proposed, and ADCP deployment locations.

Table 2.1 Toyness infrastructure.

	Existing	Proposed
Site centre	335441E, 1003699N	335385E, 1003586N
Number of pens	10	12
Pen circumference	80 m	120 m
Pen net depth	10 m	12 m
Mooring grid spacing	50 m	80 m
Layout	2 x 5	2no. 2 x 3

3 Scope

To establish the environmentally appropriate biomass and medicine consent limits for the proposal, an assessment is undertaken using NewDEPOMOD configured according to the "standard default" approach as outlined in (2019b). This requires the collection of at least 90 days of hydrographic data from the location which in this case are formed from two shorter subsets. Individually these data also support the development of a hydrodynamic model.

Prior to this a hydrographic survey in 2005 at a location to the SW of the existing site was used to support the licencing requirements here using AutoDEPOMOD. However, at 211 m from the centre of the proposal these data are not suitable to represent conditions at the latter. A bathymetric survey of the area was undertaken by the UK Hydrographic Office (UKHO) in 2009 (UKHO 2019).

4 Methods

4.1 Instrument deployment

An Acoustic Doppler Current Profiler (ADCP) was deployed at Toyness on both occasions (Table 4.1).

Table 4.1 Deployment details.

Identifier	TOYNS	Toyness
Deployment date	11/07/2018	24/09/2018
Data acquisition period	11/07/2018 14:42 to 18/09/2018 10:22 (68.8 days)	24/09/2018 13:05 to 14/11/2018 01:25 (50.5 days)
Instrument	Teledyne RDI Workhorse Sentinel	Teledyne RDI Sentinel V50

Instruments were mounted in a gimballed frame and deployed on the seabed at the target position. An 80m ground rope attached to the frame ran to a clump weight marked with a surface buoy to allow recovery. Each ADCP specification and deployment configuration is given in Section 6. Position fixes were obtained using a Garmin GPSMAP 76S in WGS84. The GPS position accuracy was compared against a known location and checked for consistency at the end of the survey. The depth at each deployment location was obtained using a Plastimo Echotest II hand-held depth sounder. Readings were later corrected to Chart Datum using predicted tidal heights for the secondary port Stromness obtained from Admiralty TotalTide software.

4.2 Data processing

Following retrieval of the ADCP the raw data file was downloaded from the instrument and imported into Teledyne's *Velocity* software, automatically averaging the raw ping data using the default screening parameters and generating the corresponding **.pdv* file used for data processing (screenshots are presented at Appendices A-D). These are given an initial inspection (e.g. orientation, pitch, roll, heading, pressure) to check that the meter has remained undisturbed and that there are no obvious breaks in the data. Side-lobe interference was removed and the data for the valid bins was exported in ASCII format. These were compiled into a Microsoft Excel workbook and evaluated according to Teledyne's *QA/QC Parameter for Acoustic Doppler Current Profilers* application.

The standard deviation (SD) for each ensemble at each bin is calculated according to:

$$cell\ SD = \frac{single\ ping\ SD}{\sqrt{\frac{(PG1 + PG4)}{100} * no.of\ pings}}$$

Where the single ping SD is specific to the instrument for a given bin size, PG1 (percent good 1) and PG4 are the percentages of 3 and 4 beam solutions respectively (i.e. valid pings) and the number of pings is that per ensemble programmed for each deployment.

Three depth bins were selected as outlined by SEPA guidance and these data were analysed using the SEPA tool *HGdata_analysis_v7.11.xls* (SEPA 2019b & SEPA 2022). All bearings were corrected from magnetic north to grid north using a Grid Magnetic Angle derived from the declination obtained for the survey position and date from the World Magnetic Model 2020 Calculator (BGS 2021), and from a grid convergence angle calculated from the deployment National Grid Reference by the HGdata_analysis spreadsheet. Deployment specific values are given in Table 4.2.

Table 4.2 Heading correction parameters.

Identifier	TOYNS	Toyness
Grid Magnetic Angle	1.51°W	1.47°W
Declination (date)	2.47°W (14/08/2018)	2.43°W (19/10/2018)
Grid Convergence Angle	0.96°W	0.96°W

For the second deployment ('Toyness') the Sentinel V50 ADCP was programmed to record two profiles; Profile 1 with 0.6m bins recording every 3 hours concurrently collecting wave and flow data, and Profile 2 with 1m bins recording with an ensemble interval of 20 minutes (except while Profile 1 was active). Following QA/QC evaluation profiles were merged to create a continuous time series, however as the Profile 1 bin size was not a multiple of that used in Profile 2 bins selected from Profile 1 are of the nearest equivalent bin centre height to those of Profile 2.

4.3 Data repair

During the TOYNS deployment beam interference is evident throughout the survey with the frequency and duration of these episodes increasing in the latter part of the data, where processing becomes increasingly dependent on a 3-beam solution to derive flow measurements. To minimise the influence of this, data processing focused on a subset that ended at a point where an appropriate join could be made to the second data set ('Toyness') to form the composite 90-day flowmetry. The selected period is from 11/7/2018 to 25/08/2018 (44.6 days).

Where quality parameters (e.g. error velocity, correlation, percent good) indicated that the remaining data may be compromised during these events, velocity and direction for the affected profiles were compared to those adjacent and from a similar point in a previous or subsequent tide.

At most, current speed was marginally depressed in some cases however in general there was no observable influence indicating an effective 3 beam solution and that no data repair was required.

No data repair was required for the second deployment.

4.4 Harmonic analysis

For each deployment the astronomic tidal component was derived using harmonic analysis to remove the influence of meteorological effects using the UTide toolbox in MATLAB. This reduces the flow to its harmonic constituents from which the tide only speed and direction are reproduced.

4.5 Data combination

The TotalTide prediction for Stromness and lunar phase information were used to align both data sets, with the full moon on the 26/08/2018 considered to be equivalent to that on the 25/9/2018. The aim was to minimise both the data used from the latter part of 'TOYNS', and that discarded from the start of 'Toyness'. Stitching the data sets together at the best fit joint identified at approximately 26/08/18 13:00 to 24/09/2018 13:00 was initially considered. However, this point in 'TOYNS' falls in the first significant period that utilised a 3-beam solution (during which current velocities become increasingly depressed and more variable, while direction trends further north than would be typical, again with more variability between ensembles). To avoid the possibility of a sudden jump between each dataset an appropriate point to stitch the data is identified 33 hours prior to this in the 'TOYNS' data at 25/08/2018 04:02 to 24/09/2018 16:25 (Table 4.3). Water level, velocity and direction data for each of the selected bins were plotted to assess and fine tune this transition with the joint flagged in each *CurrentMeterData_Toyness_'layer'90d.xlsx spreadsheet*.

The artificial timestamp for the 90-day timeseries was cast backwards from the first date of the longer second data set.

Table 4.3 Data combination tide and lunar phase details from TotalTide, secondary port 0280 Stromness.

Identifier	Part	Start	Tide height	Tide timing	End	Tide height	Tide timing
TOYNS	1	16/07/2018 13:42:38	2.7m	2 hrs after HW	25/08/2018 04:02:38	1.2m	1.5 hrs after LW
		16/07/2018 High: 11:36 3.6 m; 23:49 3.8 m Low: 05:17 0.3 m; 17:25 0.8 m 19/07/2018 19:51 27/07/2018 20:19 04/08/2018 18:17 11/08/2018 09:56 11 days until full moon One day after spring tide			25/08/2018 High: 08:41 3.1 m; 20:44 3.4 m Low: 02:27 0.9 m; 14:31 1.0 m 26/08/2018 11:55 03/09/2018 02:36 09/09/2018 18:00 16/09/2018 23:14 One day to full moon 3 days before spring tide		
Toyness	2	24/09/2018 16:25:47	1.5m	1.8 hrs after LW	14/11/2018 01:05:47	2.8m	HW (approx.)
		24/09/2018 High: 08:46 3.3 m; 20:49 3.6 m Low: 02:31 0.8 m; 14:37 0.9 m 25/09/2018 02:51 02/10/2018 09:44 09/10/2018 03:46 16/10/2018 18:00 One day to full moon 3 days before spring tide			14/11/2018 High: 01:12 2.8 m; 13:15 2.9 m Low: 06:36 1.6 m; 19:28 1.4 m 15/11/2018 14:53 23/11/2018 05:38 30/11/2018 00:17 07/12/2018 07:19 9 days until full moon 5 days after spring tide		

5 Flow data

5.1 Deployment position

The deployment positions are given in Table 5.1 and illustrated at Figure 5.1. The ADCPs were deployed approximately 150m east of the proposed site centre, adjacent to the existing pen group. The raw depth sounding was converted to chart datum using the predicted tidal height for Stromness (secondary port ID 0280) obtained from Admiralty TotalTide software. The weighted average ADCP position and depth was determined following SEPA guidance (SEPA 2022).

Table 5.1 ADCP deployment positions for Toyness.

Identifier	Date & time (UT)	Easting	Northing	Raw depth (m)	Tide (m)	Depth (mCD)
TOYNS	11/07/2018 14:42	335537	1003585	32.20	1.2	31.00
Toyness	24/09/2018 13:05	335537	1003583	32.78	1.3	31.48
Weighted average	-	335537	1003584	-	-	31.27

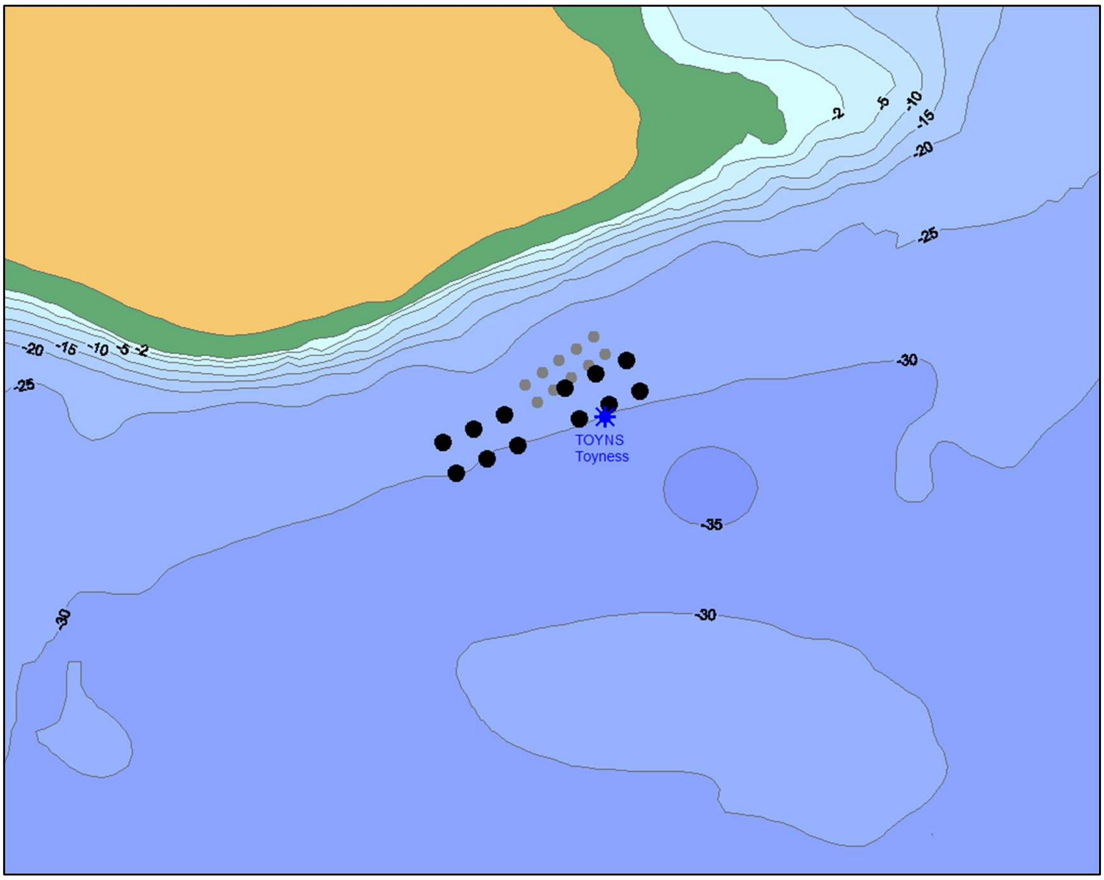


Figure 5.1 Location of the Toyness marine fish farm illustrating the ADCP deployments relative to the proposed and existing pens (black and grey respectively). Bathymetry derived from Admiralty Chart ref. 35-0.

5.2 Description – 'TOYNS', 2018

5.2.1 Quality

The first 3,209 ensembles were selected for processing from TOYNS. With a 20-minute interval this equates to 44.6 days. Heading, pitch and roll sensor data show minor variation during the deployment (Appendix B).

The recorded pressure was compared with the estimated tidal heights for Stromness which shows that both range and timing are relatively consistent with those predicted. The range is slightly greater in the observations while high water occurring marginally earlier than that predicted at Stromness, and low water occurring at the predicted time. The pressure record indicates that the mean depth during the deployment including the height of the frame, was 33.3m and the minimum depth was 31.2mCD. This corresponds well with the deployment depth of 31.0mCD.

The mean SD for all 3,209 ensembles for bins 1 to 26 is 0.0035 m s^{-1} and is therefore below the SEPA guideline threshold for horizontal precision by not exceeding 10% of the mean velocity recorded (0.070 m s^{-1}, bins 1-26).

5.2.2 Depth bin selection

Bins 1, 20 and 25 were selected to represent near-bed, pen-bottom and sub-surface conditions respectively, detailed in Table 5.2. The near-bed bin is at a depth within 3 m above the seabed. The pen-bottom bin was selected from a depth corresponding to the bottom of the pens at the mean depth observed during the deployment period. The sub-surface bin was selected from a depth to be within 5 m of the lowest observed tide during the deployment, while being below potential effects from wave breaking or side-lobe interference.

Table 5.2 Bin selection (TOYNS).

	Position of bin centre (metres)			
Bin number	From sensor head	From seabed	From the mean tidal level	From lowest observed tide
1	2.11	**2.71**	30.65	28.53
20	21.11	21.71	**11.65**	9.53
25	26.11	26.71	6.65	**4.53**

5.2.3 Analysis

The summary statistics for ensembles 221 to 3,429 equivalent to the period from 11/07/2018 14:42:38 to 25/08/2018 04:02:38 (44.56 days) of each bin selected are given in Table 5.3.

Table 5.3 'TOYNS' summary statistics.

	Near-bed	Pen-bottom	Sub-surface
Mean velocity (m s^{-1})	0.055	0.076	0.078
Min velocity (m s^{-1})	0.001	0.002	0.001
Max velocity (m s^{-1})	0.178	0.274	0.337
Ranked percentage 0.095 m s^{-1}	87.0 %	68.2 %	67.6 %
Major axis (°G)	245	255	255
Amplitude anisotropy	2.82	3.36	3.75
Residual velocity (m s^{-1})	0.035	0.032	0.019
Residual direction (°G)	257.5	251.8	251.4
Parallel Residual (m s^{-1})	0.034	0.032	0.019
Normal Residual (m s^{-1})	0.008	-0.002	-0.001
Parallel tidal amplitude (m s^{-1})	0.071	0.109	0.122
Normal tidal amplitude (m s^{-1})	0.025	0.033	0.033
	Min	**Max**	**Range**
Depth (m)	31.2	35.2	4.0

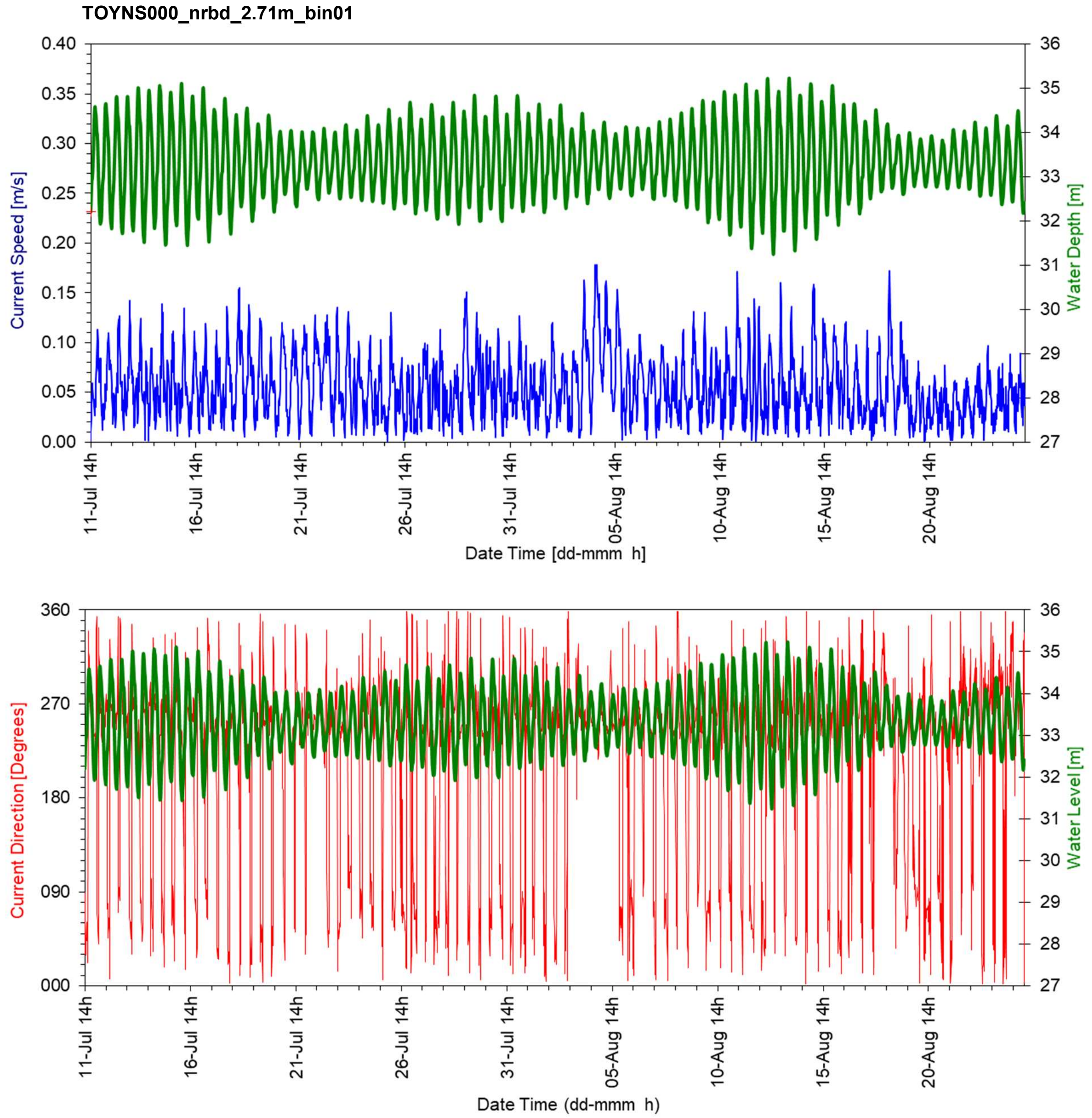


Figure 5.2 Near-bed time series plots for current speed and direction against water level.

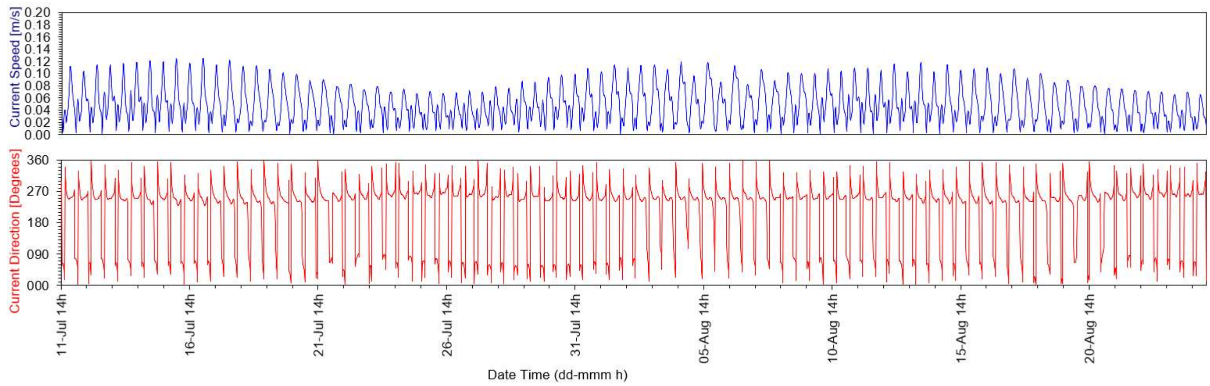


Figure 5.3 Near-bed time series plots for harmonic reproduction of speed and direction.

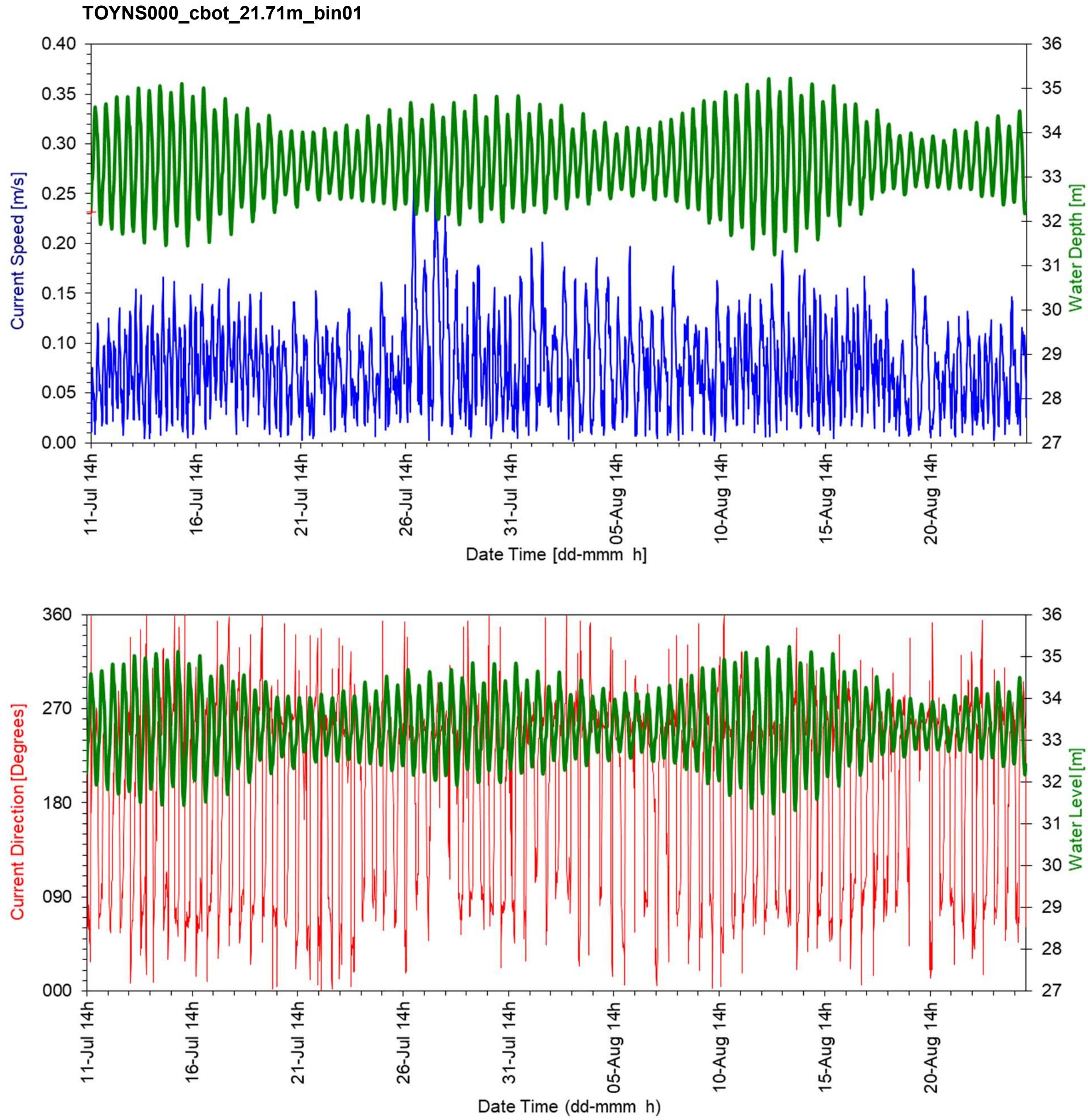


Figure 5.4 Pen-bottom time series plots for current speed and direction against water level.

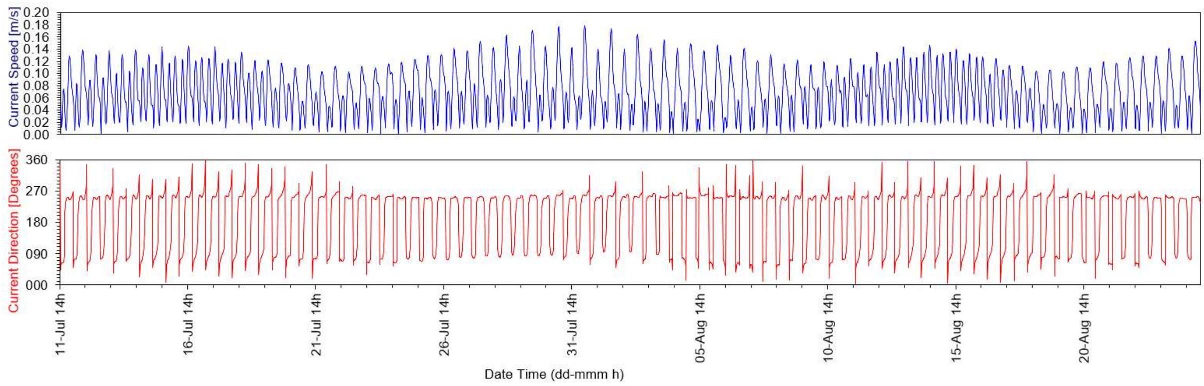


Figure 5.5 Pen-bottom time series plots for harmonic reproduction of speed and direction.

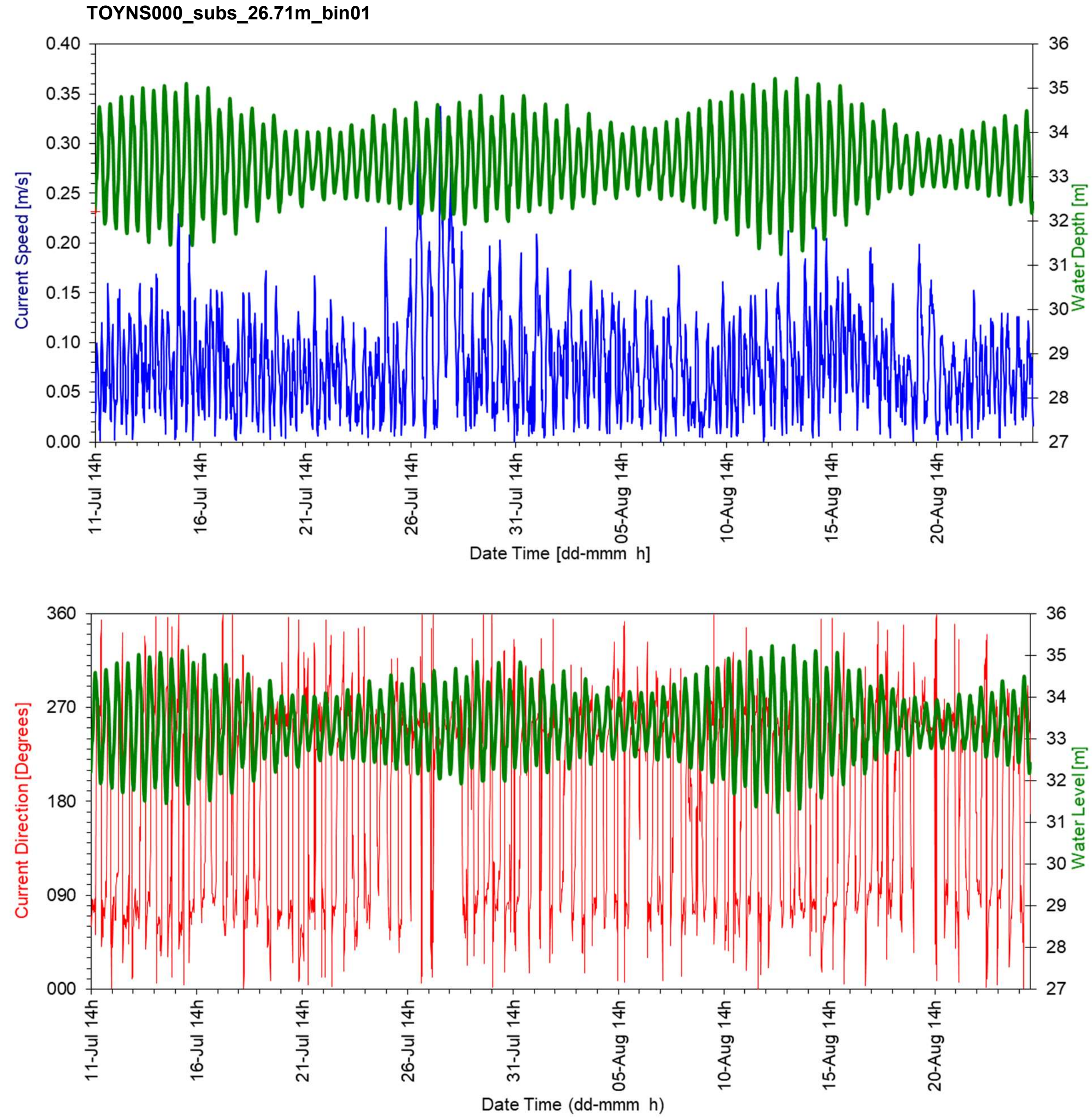


Figure 5.6 Sub-surface time series plots for current speed and direction against water level.

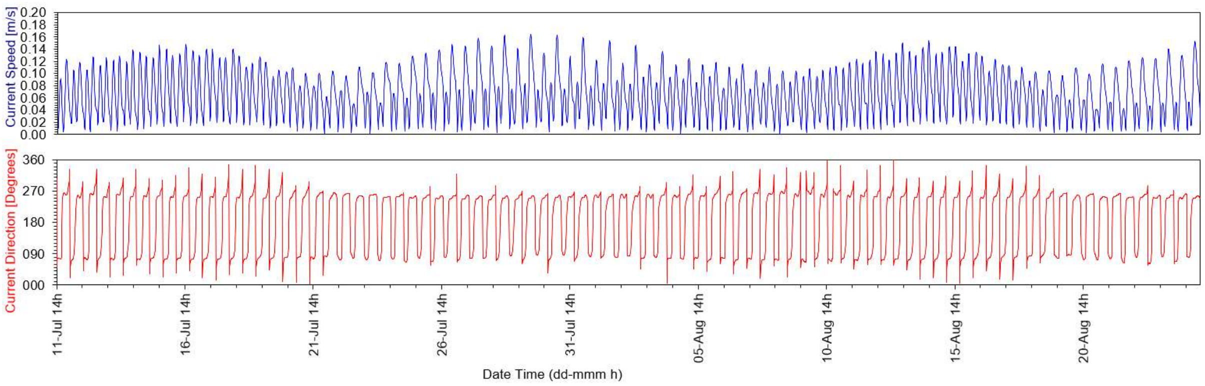


Figure 5.7 Sub-surface time series plots for harmonic reproduction of speed and direction.

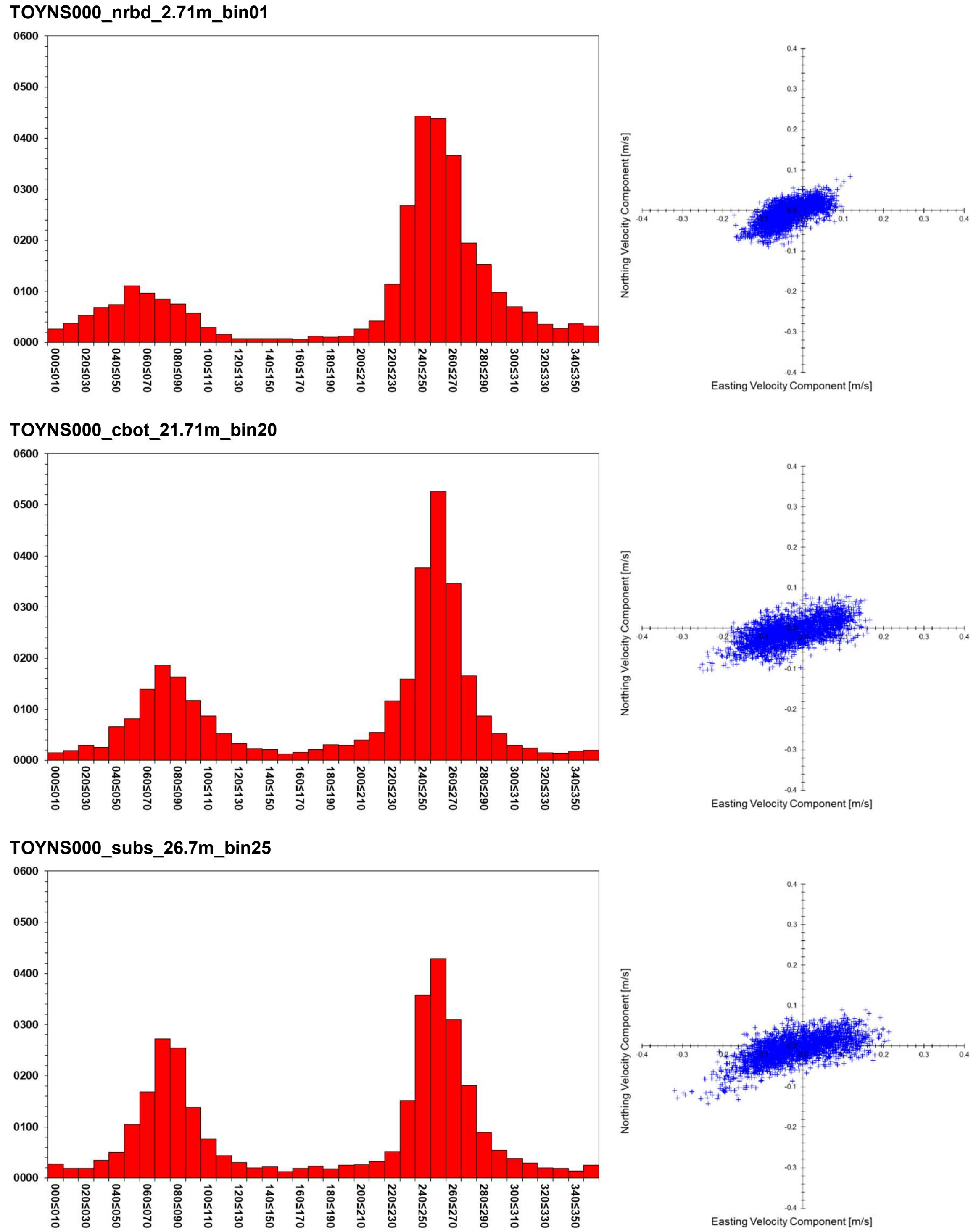


Figure 5.8 Current direction frequency plots and easting and northing velocity component scatter plots for the Near-bed, pen-bottom and near-surface bins.

5.3 Description – 'Toyness', 2018

5.3.1 Quality

A total of 3,638 valid ensembles combined from the two profiles were processed from the 'Toyness' deployment. With a 20-minute interval this equates to 50.51 days. Heading, pitch and roll sensor data show minor variation during the deployment (Appendix B).

The recorded pressure was compared with the estimated tidal heights for Stromness with no departure from the characteristics observed for the TOYNS deployment. The pressure record indicates that the mean depth during the deployment including the height of the frame, was 33.4 m and the minimum depth was 31.4 mCD. This corresponds well with the deployment depth of 31.5 mCD.

For Profile 1 the mean SD for all 405 ensembles for bins 1 to 44 is 0.0026 m s^{-1} and is therefore below the SEPA guideline threshold for horizontal precision by not exceeding 10% of the mean velocity recorded (0.0674 m s^{-1}, bins 1-44). For Profile 2 the mean SD for all 3,233 ensembles for bins 1 to 26 is 0.0037 m s^{-1} and therefore also meets the SEPA guideline threshold (mean velocity 0.0691 m s^{-1}, bins 1-26).

5.3.2 Depth bin selection

Bins 1, 20 and 25 were selected to represent near-bed, pen-bottom and sub-surface conditions respectively, detailed in Table 5.4. The near-bed bin is at a depth within 3 m above the seabed. The pen-bottom bin was selected from a depth corresponding to the bottom of the pens at the mean depth observed during the deployment period. The sub-surface bin was selected from a depth to be within 5 m of the lowest observed tide during the deployment, while being below potential effects from wave breaking or side-lobe interference.

Table 5.4 Bin selection (Toyness).

	Position of bin centre (metres)			
Bin number	From sensor head	From seabed	From the mean tidal level	From lowest observed tide
1	2.23	**2.83**	30.60	28.58
20	21.23	21.83	**11.60**	9.58
25	26.23	26.83	6.60	**4.58**

5.3.3 Analysis

The summary statistics for ensembles 9-3646 equivalent to the period from 24/09/2018 13:05:47 to 14/11/2018 01:25:47 (50.51 days) of each bin selected are given in Table 5.5.

Table 5.5 'Toyness' summary statistics.

	Near-bed	**Pen-bottom**	**Sub-surface**
Mean velocity (m s^{-1})	0.063	0.069	0.071
Min velocity (m s^{-1})	0.001	0.001	0.001
Max velocity (m s^{-1})	0.241	0.344	0.369
Ranked percentage 0.095 m s^{-1}	81.4%	76.2%	75.8%
Major axis (°G)	250	255	255
Amplitude anisotropy	2.20	3.41	3.09
Residual velocity (m s^{-1})	0.024	0.013	0.009
Residual direction (°G)	259.9	238.0	205.3
Parallel Residual (m s^{-1})	0.023	0.012	0.006
Normal Residual (m s^{-1})	0.004	-0.004	-0.007
Parallel tidal amplitude (m s^{-1})	0.088	0.107	0.109
Normal tidal amplitude (m s^{-1})	0.040	0.031	0.035
	Min	**Max**	**Range**
Depth (m)	31.4	35.4	5.0

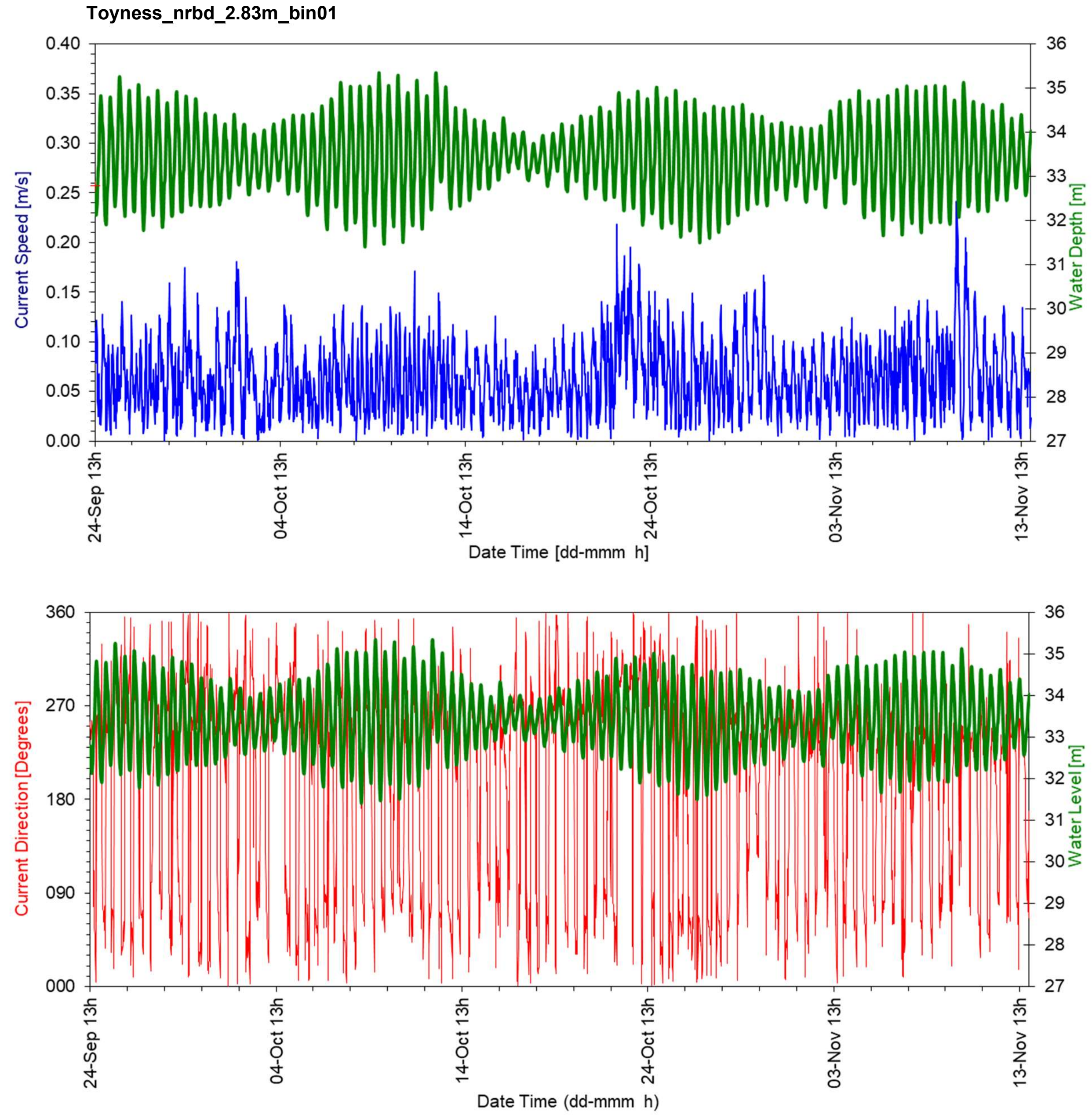


Figure 5.9 Near-bed time series plots for current speed and direction against water level.

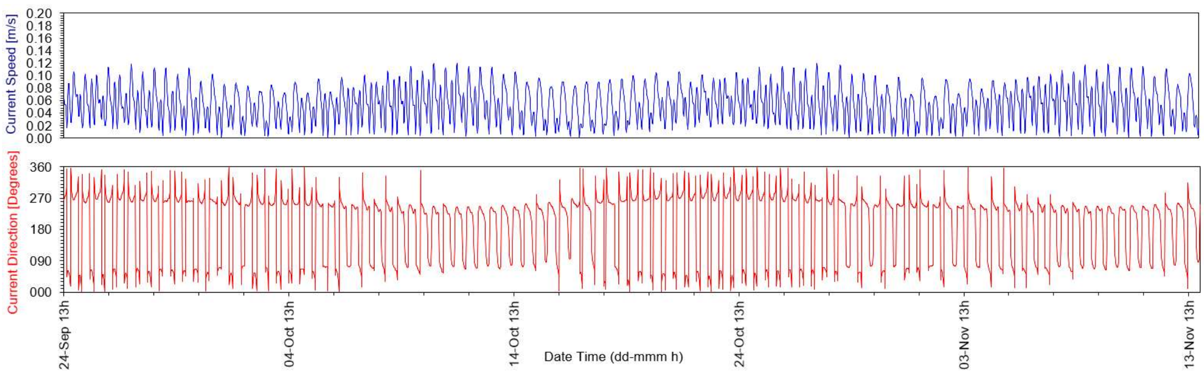


Figure 5.10 Near-bed time series plots for harmonic reproduction of speed and direction.

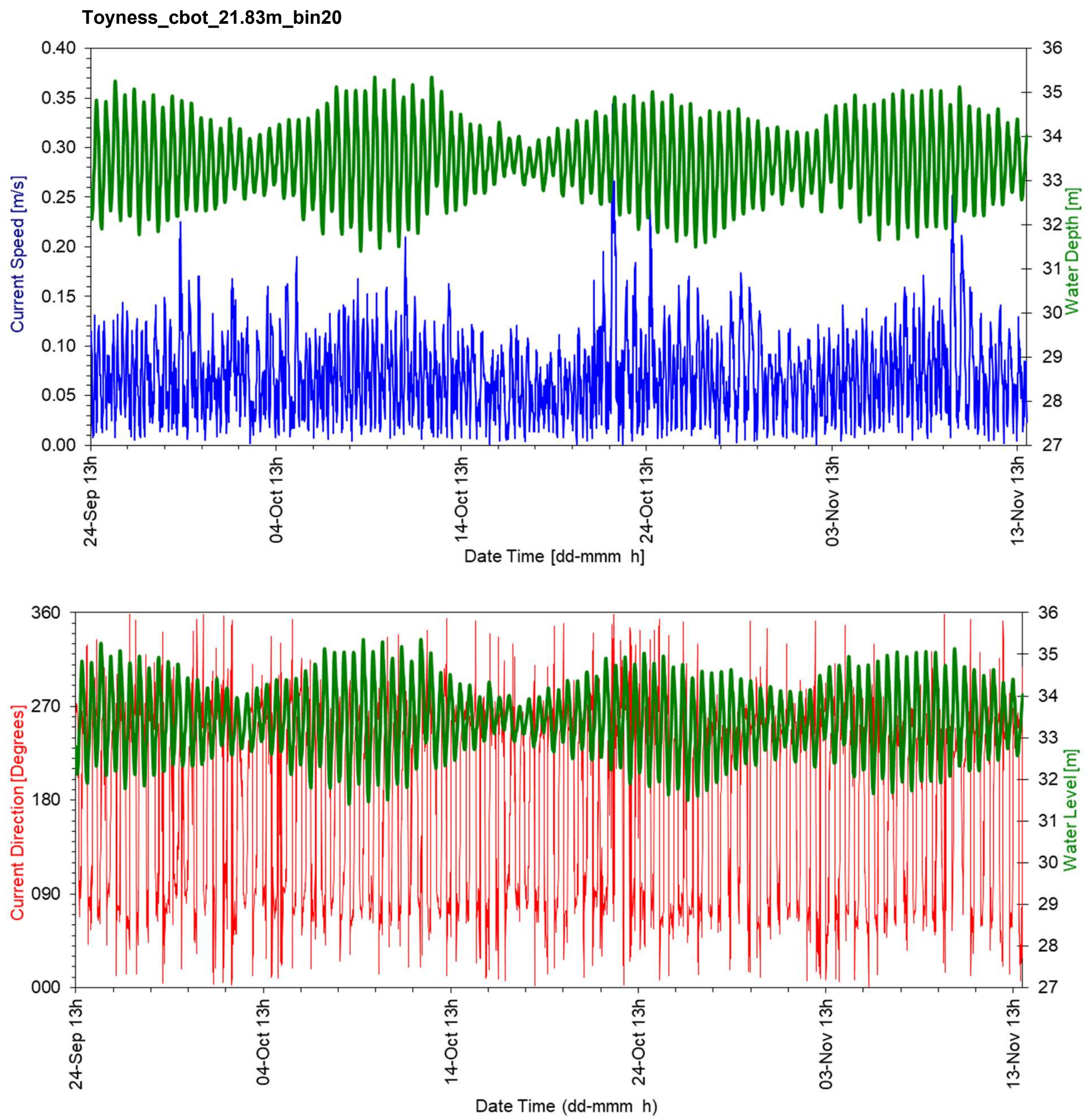


Figure 5.11 Pen-bottom time series plots for current speed and direction against water level.

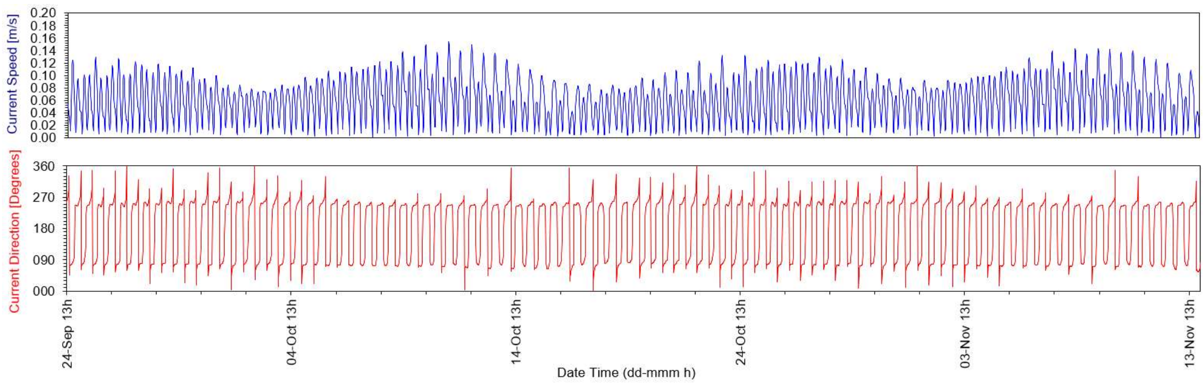


Figure 5.12 Pen-bottom time series plots for harmonic reproduction of speed and direction.

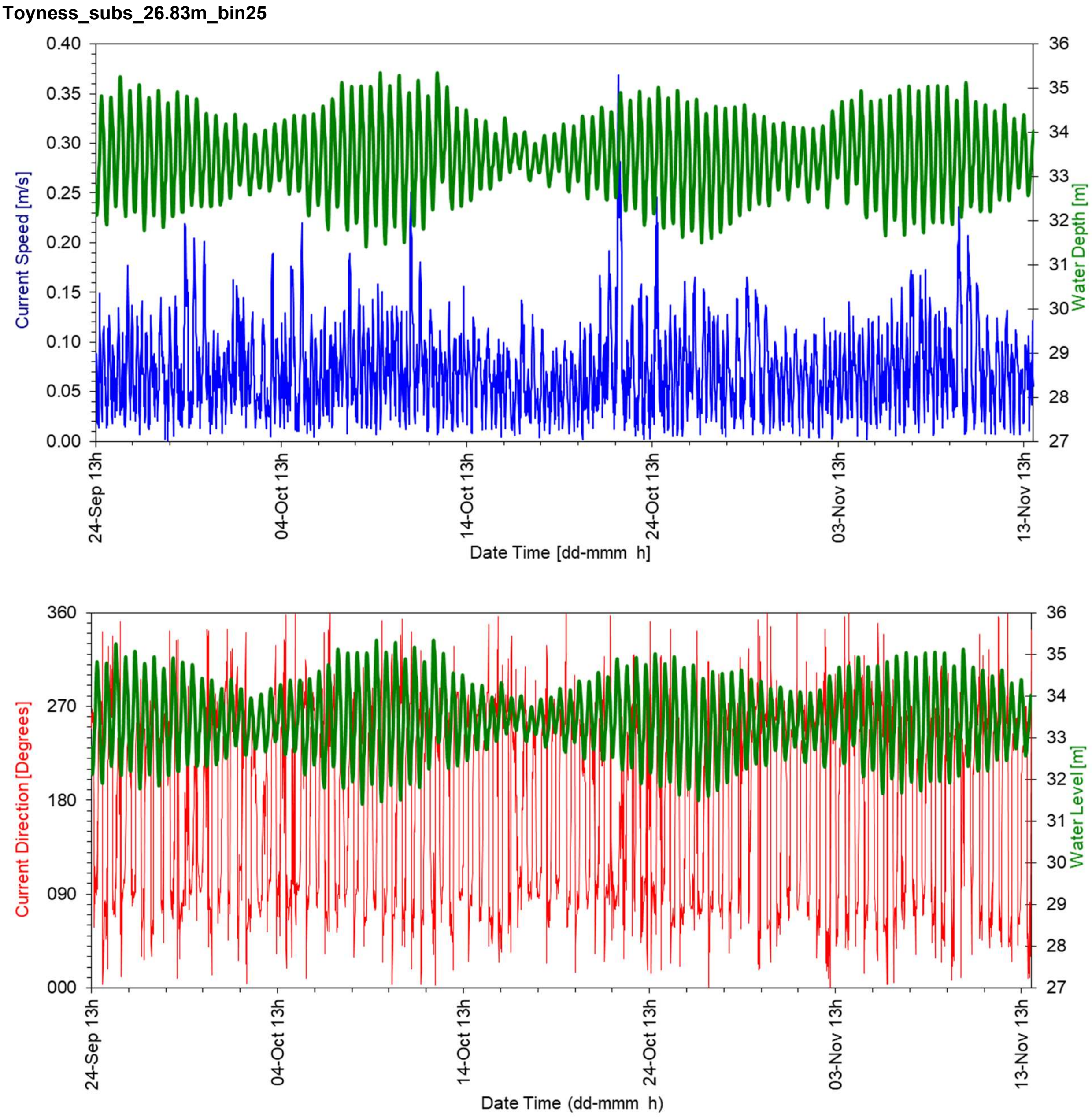


Figure 5.13 Sub-surface time series plots for current speed and direction against water level.

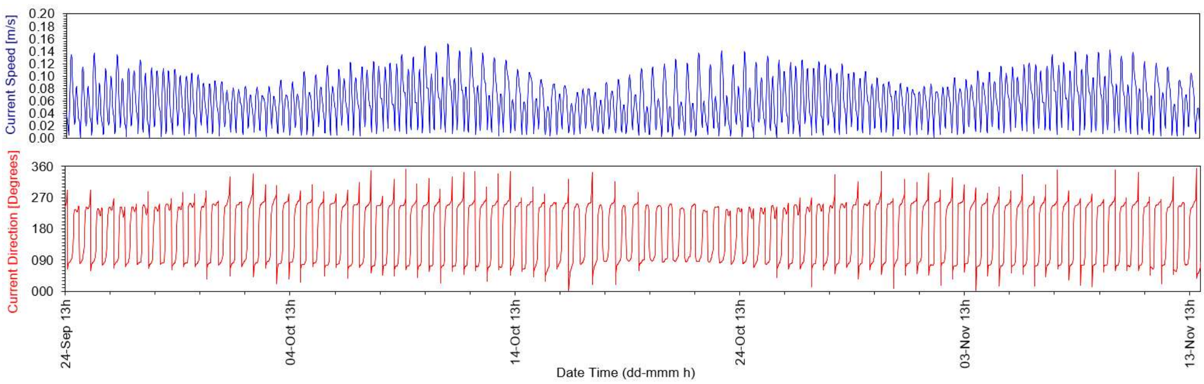
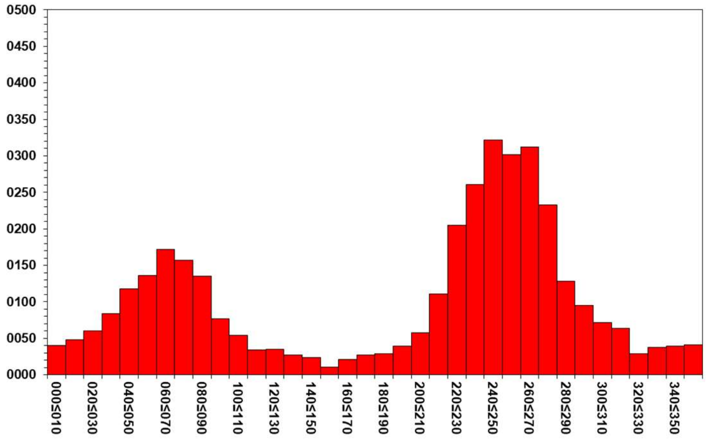
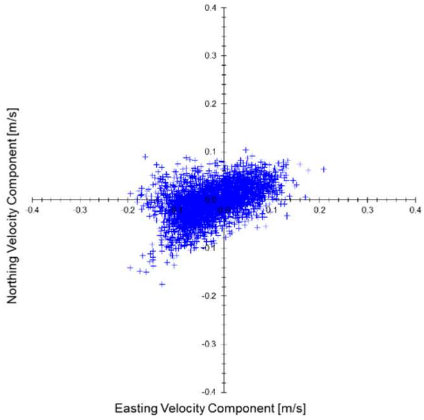


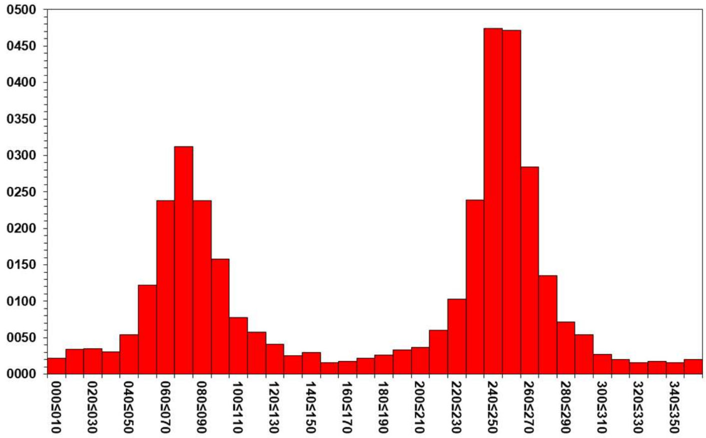
Figure 5.14 Sub-surface time series plots for harmonic reproduction of speed and direction.

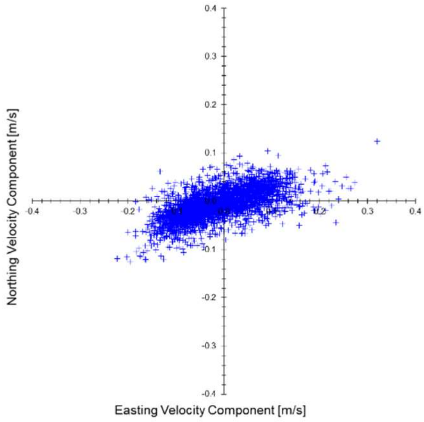
Toyness_nrbd_2.83m_bin01



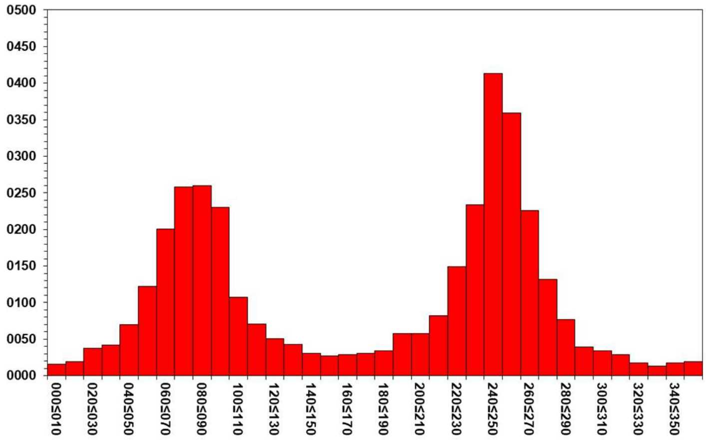


Toyness_cbot_21.8m_bin20





Toyness_subs_26.83m_bin25



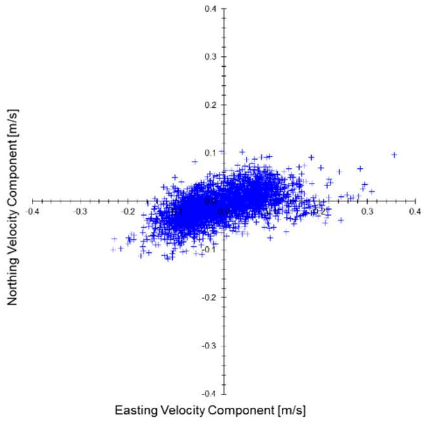


Figure 5.15 Current direction frequency plots and easting and northing velocity component scatter plots for the Near-bed, pen-bottom and near-surface bins.

5.4 Description – Composite 90-day data

5.4.1 Analysis

The composite data comprise 39.6 days of 'TOYNS' followed by 50.4 days of 'Toyness'. Weighted averaging was used to calculate appropriate heights above seabed for the selected bins following stitching as per SEPA 2022. The summary statistics for the 90-day composite data for these bins are given in Table 5.6 below.

Table 5.6 Composite 90-day data summary statistics.

	Near-bed	Pen-bottom	Sub-surface
Weighted average bin height (m)	2.78	21.78	26.78
Mean velocity (m s^{-1})	0.059	0.073	0.074
Min velocity (m s^{-1})	0.001	0.001	0.001
Max velocity (m s^{-1})	0.241	0.344	0.369
Ranked percentage 0.095 m s^{-1}	84.0%	72.6%	72.2%
Major axis (°G)	250	255	255
Amplitude anisotropy	2.3	3.4	3.4
Residual velocity (m s^{-1})	0.029	0.023	0.014
Residual direction (°G)	258.5	247.5	234.9
Residual to mean velocity ratio	48.1%	31.0%	18.7%
Parallel Residual (m s^{-1})	0.028	0.022	0.013
Normal Residual (m s^{-1})	0.004	-0.003	-0.005
Parallel tidal amplitude (m s^{-1})	0.081	0.109	0.115
Normal tidal amplitude (m s^{-1})	0.035	0.032	0.034

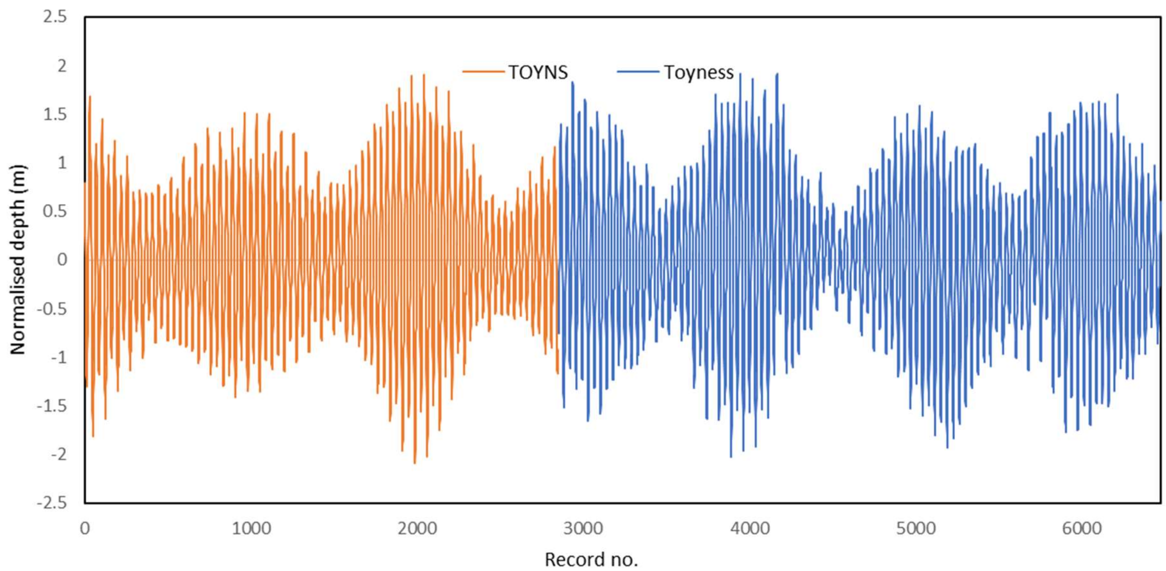


Figure 5.16 Time series of composite 90-day normalised water level indicating the stitch point between 'TOYNS' and 'Toyness'.

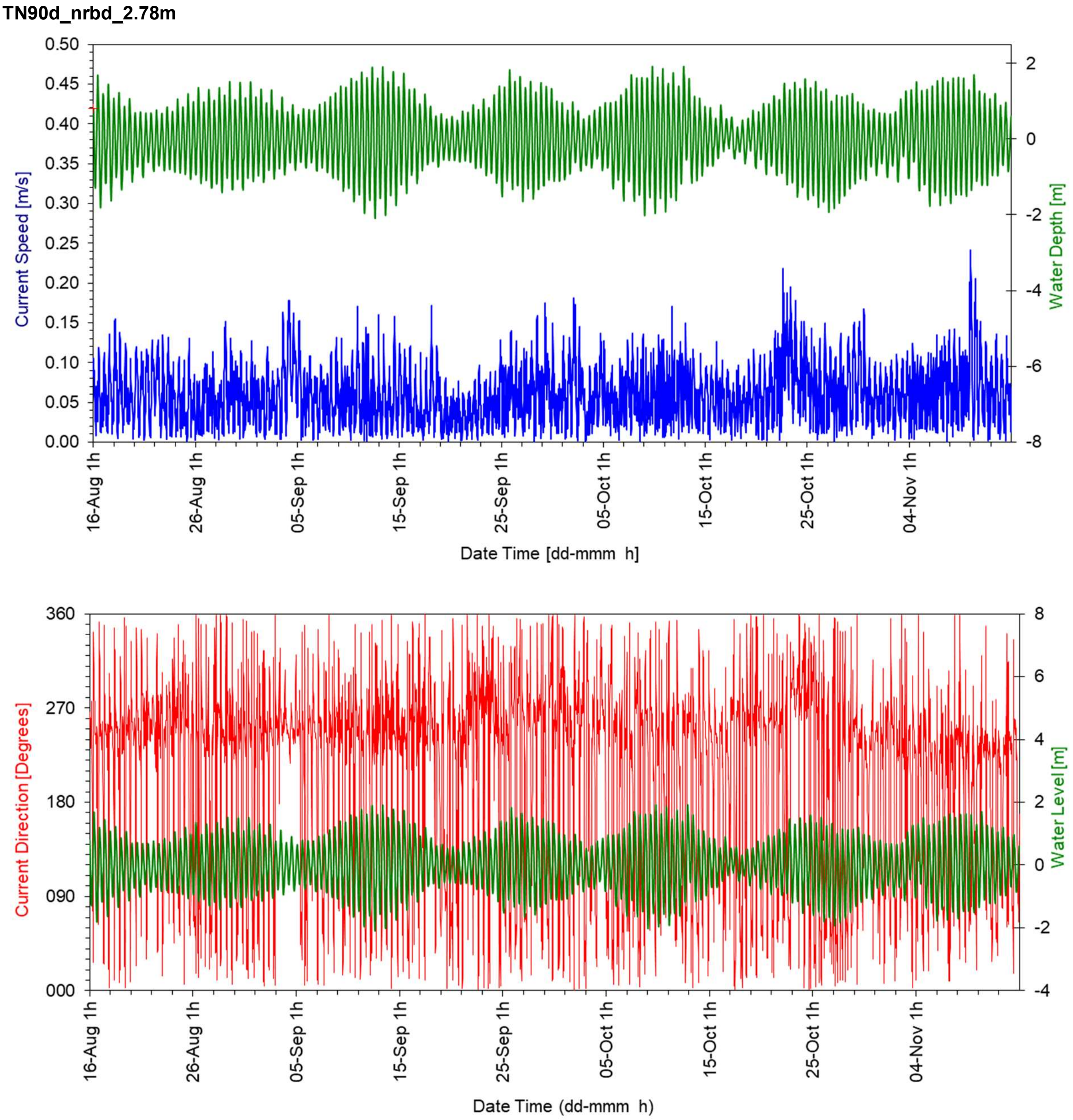


Figure 5.17 Near-bed time series of composite 90-day for current speed and direction against water level.

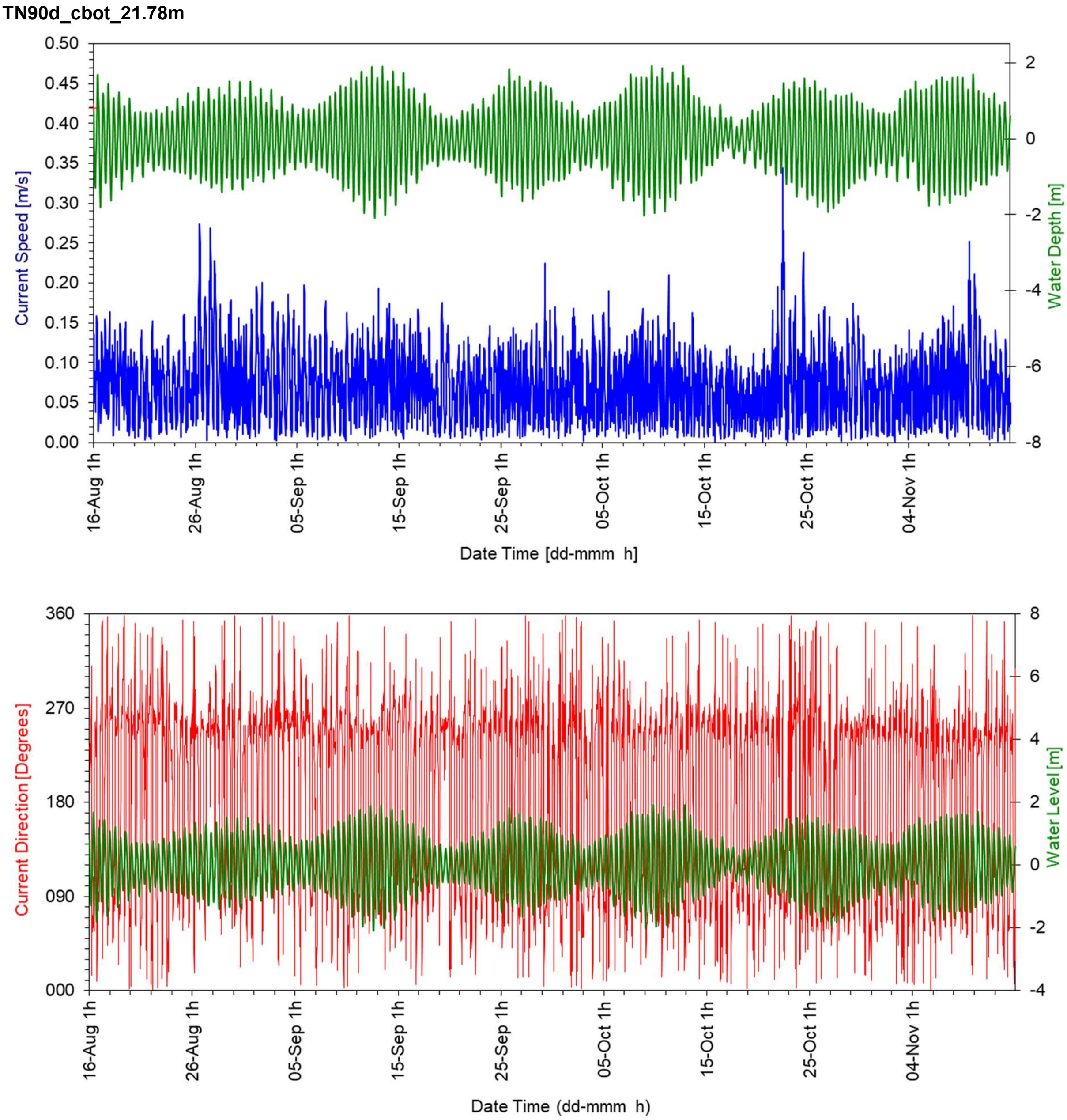
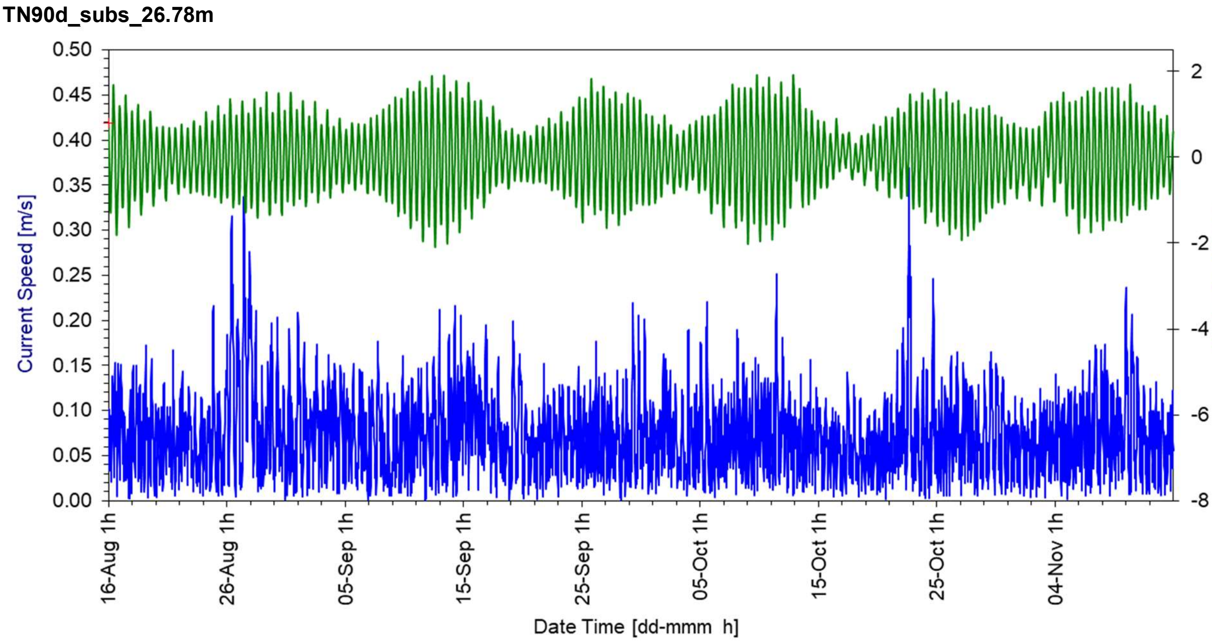


Figure 5.18 Pen-bottom time series of composite 90-day current speed and direction against water level.



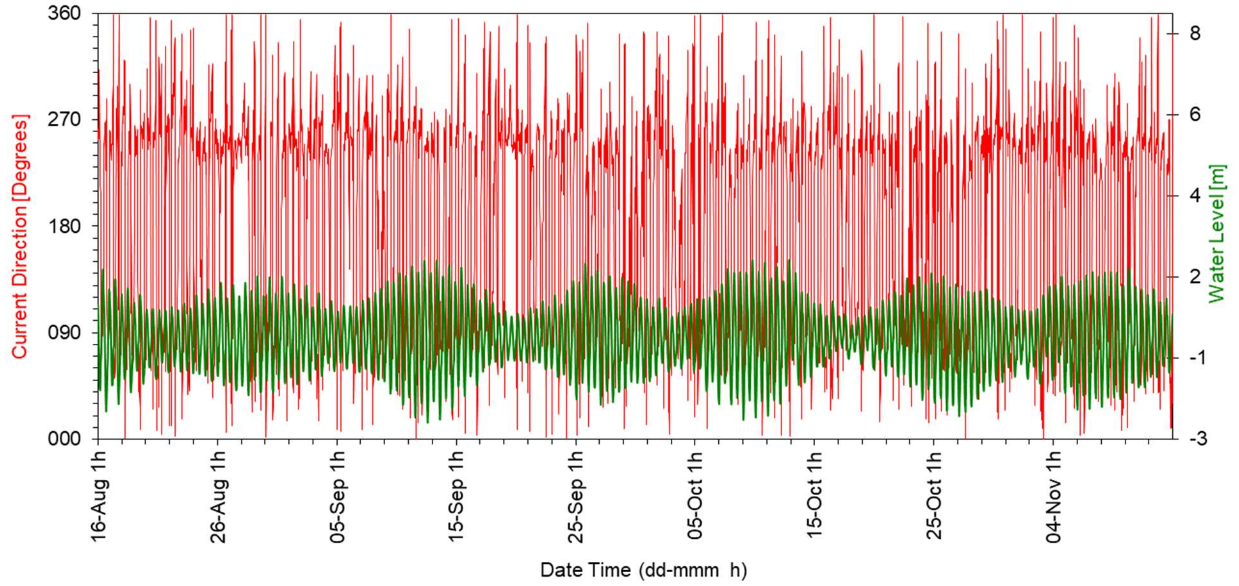


Figure 5.19 Sub-surface time series of composite 90-day current speed and direction against water level.

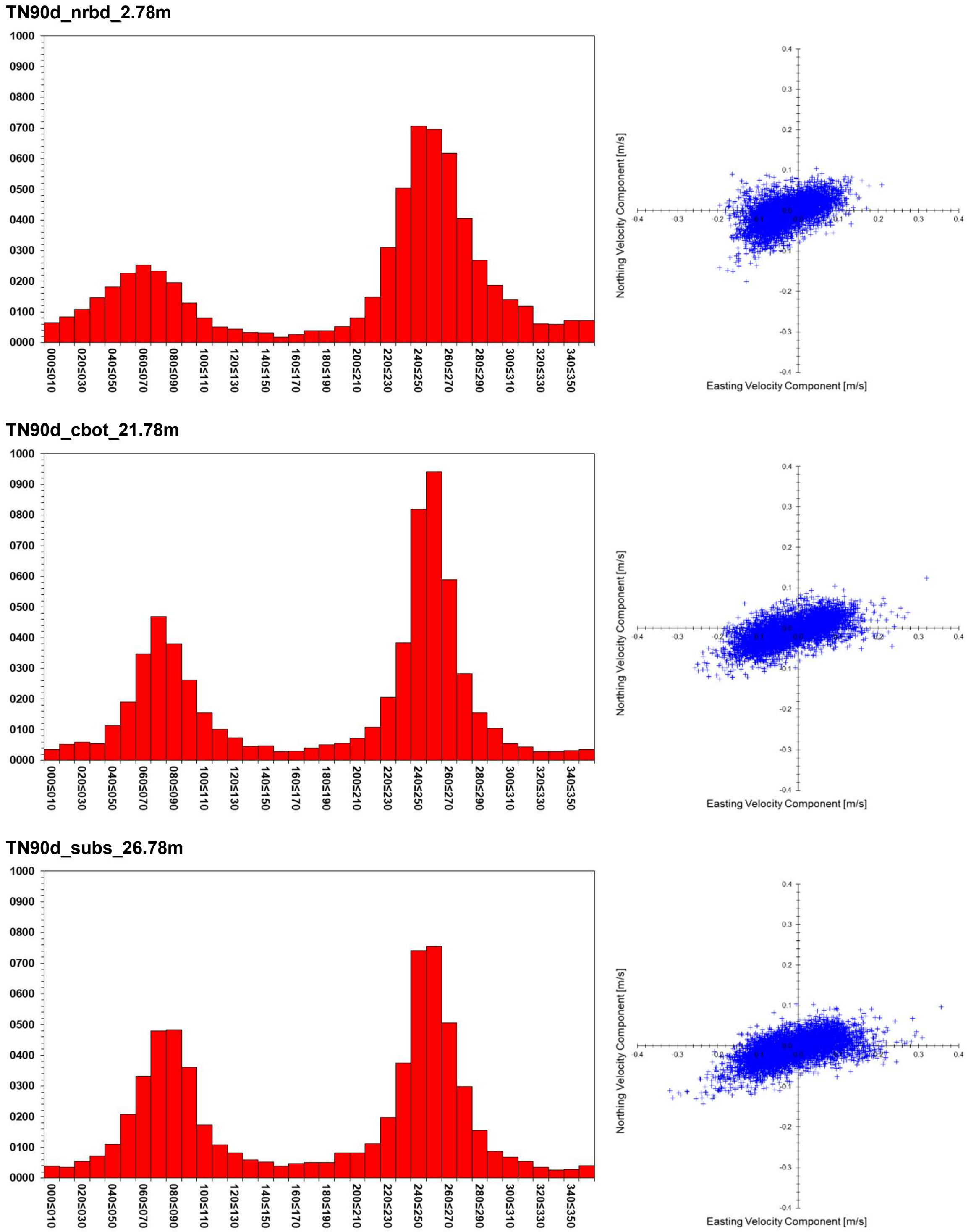


Figure 5.15 Current direction frequency plots and easting and northing velocity component scatter plots for the Near-bed, pen-bottom and near-surface bins.

5.5 Summary

The data are indicative of a moderately flushed site with a clear tidal signature. Currents are aligned along a WSW-ENE axis parallel to the shoreline, with more variability at depth. Peak speeds are broadly similar on both tides, with the WSW ebb tide flowing from high water through to the early flood tide ebb, therefore persisting for longer than the ENE flood tide. Modification to this pattern is apparent particularly during neap tides which indicates susceptibility to wind influence at this location, however dominance of the ebb tide results in moderate residual currents throughout the water column to the WSW towards Hoy Sound.

Data combination is successful with commonality observed between the two data sets, separated by approximately one month. The data are considered representative of conditions at the site and suitable for use in modelling. The magnitude of the near-seabed residual currents exceeds 35% of the mean velocity requiring that NewDEPOMOD is forced with flowmetry where the residual current has been removed.

6 Equipment set-up parameters and specifications

Table 6.1 ADCP configurations

Deployment name	TOYNS	Toyness	
Instrument	Teledyne RDI Workhorse Sentinel ADCP	Teledyne RDI Sentinel V50 ADCP	
Serial number	16781	23953	
Frequency (kHz)	614	492	
Profile	n/a	1	2
First viable ensemble (no.)	221	2	8
Last viable ensemble (no.)	3,429	406	3,240
Bin size (m)	1.0	0.6	1.0
Blanking distance (m)	0.88	1.0	1.0
No. of bins	34	57	34
First bin range (m)	2.11	1.88	2.23
Ensemble interval (s)	1,200	10,800	1,200
Number of pings	400	2,100	400
Ping interval (s)	3	0.5	1.0
Ambiguity velocity (m s^{-1})	1.75	1.75	1.75
Bandwidth (%)	25	25	25
Theoretical standard deviation (m s^{-1})	0.0035	0.0026	0.0037

		1200 kHz		600 kHz		300 kHz	
Water Profiling	Depth Cell Size[1]	Typical Range[2] 12 m		Typical Range[2] 50 m		Typical Range[2] 110 m	
	Vertical Resolution	Range[3]	Std. Dev.[4]	Range[3]	Std. Dev.[4]	Range[3]	Std. Dev.[4]
	0.25 m	11 m	14.0 cm/s				
	0.5 m	12 m	7.0 cm/s	38 m	14.0 cm/s	see note[1]	
	1 m	13 m	3.6 cm/s	42 m	7.0 cm/s	83 m	14.0 cm/s
	2 m	15 m[2]	1.8 cm/s	46 m	3.6 cm/s	93 m	7.0 cm/s
	4 m	see note[1]		51 m[2]	1.8 cm/s	103 m	3.6 cm/s
	8 m					116 m[2]	1.8 cm/s
Long Range Mode	2 m	19 m	3.4 cm/s				
	4 m			66 m	3.6 cm/s		
	8 m					154 m	3.7 cm/s
Profile Parameters	Velocity accuracy	0.3% of water velocity relative to ADCP ±0.3 cm/s		0.3% of water velocity relative to ADCP ±0.3 cm/s		0.5% of water velocity relative to ADCP ±0.5 cm/s	
	Velocity resolution	0.1 cm/s		0.1 cm/s		0.1 cm/s	
	Velocity range	±5 m/s default, ±20 m/s max		±5 m/s default, ±20 m/s max		±5 m/s default, ±20 m/s max	
	Number of depth cells	1–255		1–255		1–255	
	Ping rate	Typical 4 Hz, Max. 10 Hz		Typical 2 Hz, Max. 10 Hz		Typical 1 Hz, Max. 10 Hz	
Echo Intensity Profile	Vertical resolution	Depth cell size, user configurable					
	Dynamic range	80 dB					
	Precision	±1.5 dB					
Transducer and Hardware	Beam angle	20°					
	Configuration	4-beam, convex					
	Internal memory	Two PCMCIA card slots; one memory card included					
	Communications	RS-232 or RS-422; ASCII or binary output at 1200-115,200 baud					
Standard Sensors	Temperature (mounted on transducer)	Range -5° to 45°C, Precision ±0.4°C, Resolution 0.01°					
	Tilt	Range ±15°, Accuracy ±0.5°, Precision ±0.5°, Resolution 0.01°					
	Compass (fluxgate type, includes built-in field calibration feature)	Accuracy ±2°[5], Precision ±0.5°[5], Resolution 0.01°, Maximum tilt ±15°					

Figure 6.1 Teledyne RDI Workhorse Sentinel technical specifications

Depth Cell Size[1]		V20 (1000 kHz)		V50 (500 kHz)		V100 (300 kHz)	
	Depth Cell Size[1]	Range (m)[2,3] Wide/Narrow	Std Dev (cm/s)[3,4] Wide/Narrow	Range (m)[2,3] Wide/Narrow	Std Dev (cm/s)[3,4] Wide/Narrow	Range (m)[2,3] Wide/Narrow	Std Dev (cm/s)[3,4] Wide/Narrow
	0.25 m	18.0/22.6	19.2/36.5				
	0.3 m	19.3/24.0	11.1/20.8				
	0.5 m	20.2/24.9	11.1/20.8	44.1/57.6	19.2/36.5		
	1.0 m	22.1/26.9	3.6/6.7	50.5/64.6	7.1/13.5	94.5/120.6	10.9/20.6
	2.0 m	24.5/29.4	1.7/3.2	56.0/70.6	3.6/6.7	103.5/130.4	5.5/10.3
	4.0 m	26.9/32.0	0.8/1.6	63.1/78.2	1.7/3.2	114.6/142.3	2.7/5.2
	6.0 m			67.4/82.8	1.1/2.1	121.7/151.5	1.8/3.3
Self-Contained (SC) Commss and Recording	Wireless/Ethernet[7], Internal memory			802.11 b/g/n / TCPIP; One 16 GB micro SD card included			
Real-Time (RT) Communications	Serial/Ethernet[7]			RS422 / TCPIP (setup) UDP (output)			
Profile Parameters	Center Frequency			V20/V50: 0.3% of the water velocity relative to the ADCP ± 0.3 cm/s; V100: 0.5% of the water velocity relative to the ADCP ± 0.5 cm/s			
	Velocity resolution			0.1 cm/s			
	Velocity range			± 5m/s (default); ± 20m/s (maximum)			
	Ping rate			Up to 4 Hz (SC); Up to 16 Hz (RT)			
Echo Intensity Profile	Vertical resolution			Depth cell size			
	Dynamic range			80 dB			
	Precision			±1.5 dB			
Transducer and Hardware	Beam angle			25°			
	Configuration			4-beam, convex; 5th beam vertical			
	Depth rating			200 m			
	Materials			Transducer, housing, and end cap: plastic; Connector: metal shell			
Standard Sensors	Temperature (mounted on transducer)			Range -5° to 45°C, precision ± 0.4°C, resolution 0.1°			
	Compass (magneto-inductive sensor)			Accuracy 2° RMS, resolution 0.1°, max. dip angle 85°			
	Tilt (MEMS accelerometers)			Pitch range ± 90°, roll range ± 180°, accuracy 2° RMS, precision 0.05° RMS, resolution 0.1°			
	Pressure sensor (mounted on transducer)			Range 300m, accuracy 0.1% FS			
	Recorder			16GB Micro SD Card			

Figure 6.2 Teledyne RDI Sentinel V50 technical specifications

7 List of data files

'TOYNS'	
Raw current meter data	*TOYNS000.000*
Processed data, Velocity format	*TOYNS000.000.pdv*
Raw current meter data ASCII exports, compiled	*TOYNS000_ADCP_Extracts.xlsx*
Processed HG data and summary statistics.	*CurrentMeterData_TOYNS_Surface2018.xlsx* *CurrentMeterData_TOYNS_Middle2018.xlsx* *CurrentMeterData_TOYNS_Bottom2018.xlsx*
SEPA HG Data Analysis workbooks	*TOYNS000_NS_HGdata_analysis_v7.xls* *TOYNS000_CB_HGdata_analysis_v7.xls* *TOYNS000_NB_HGdata_analysis_v7.xls*
'Toyness'	
Averaged current meter data (from raw data *Toyness 20180924T112542.pd0*)	*Toyness.averaged.pdv*
Raw current meter data ASCII exports, compiled	*Toyness_ADCP_Extracts.xlsx*
Processed HG data and summary statistics.	*CurrentMeterData_Toyness_Surface2018.xlsx* *CurrentMeterData_Toyness_Middle2018.xlsx* *CurrentMeterData_Toyness_Bottom2018.xlsx*
SEPA HG Data Analysis workbooks	*Toyness_NS_HGdata_analysis_v7.xls* *Toyness_CB_HGdata_analysis_v7.xls* *Toyness_NB_HGdata_analysis_v7.xls*
90-day composite data	
Detailed velocity and water level plots	*TN_Composite90d_Plots.xlsx*
Processed HG data and summary statistics.	*CurrentMeterData_Toyness_Surface90d.xlsx* *CurrentMeterData_Toyness_Middle90d.xlsx* *CurrentMeterData_Toyness_Bottom90d.xlsx*
SEPA HG Data Analysis workbooks	*TN90d_NS_HGdata_analysis_v7.xls* *TN90d_CB_HGdata_analysis_v7.xls* *TN90d_NB_HGdata_analysis_v7.xls*

8 References

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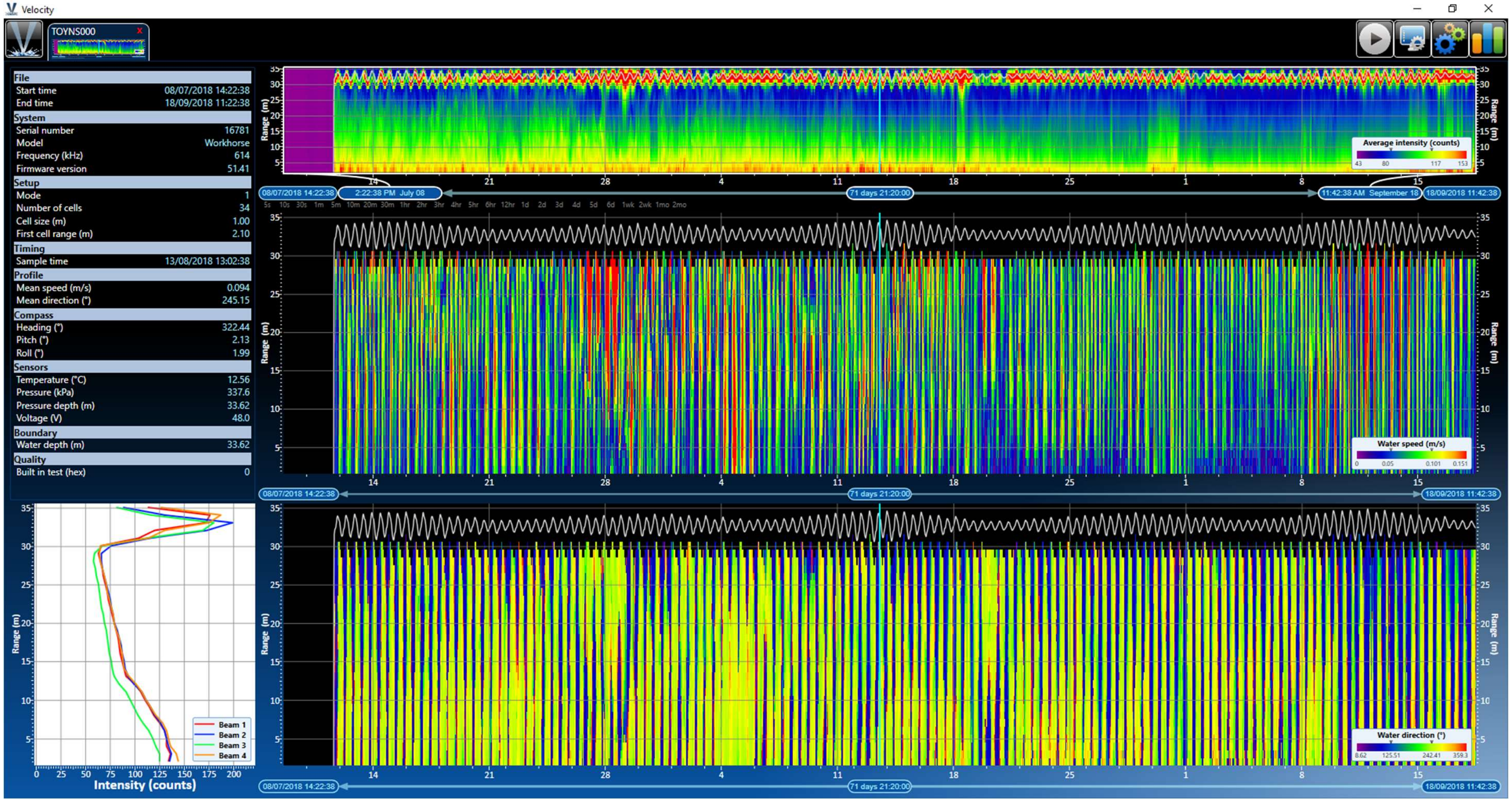
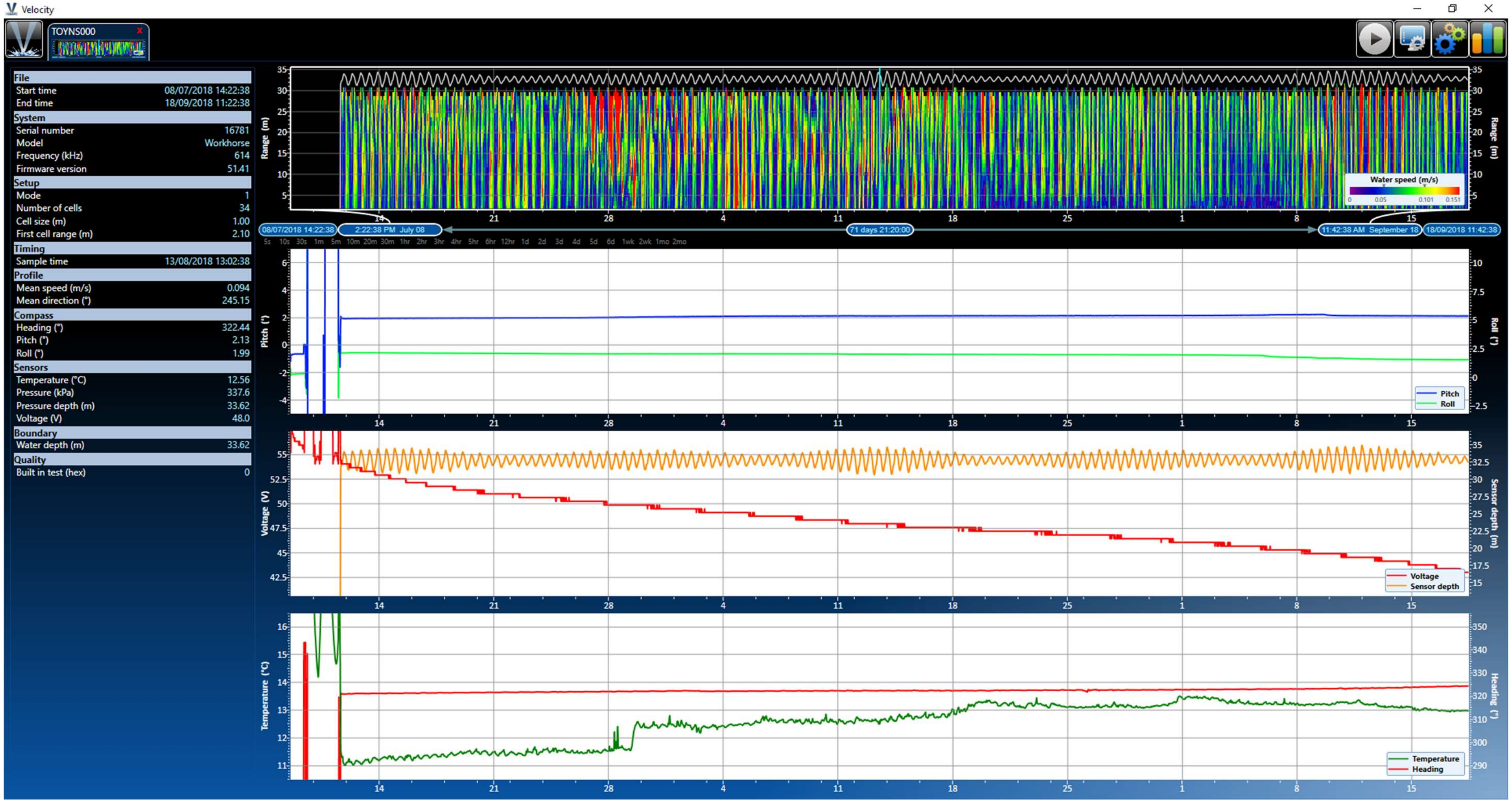
9 Appendices

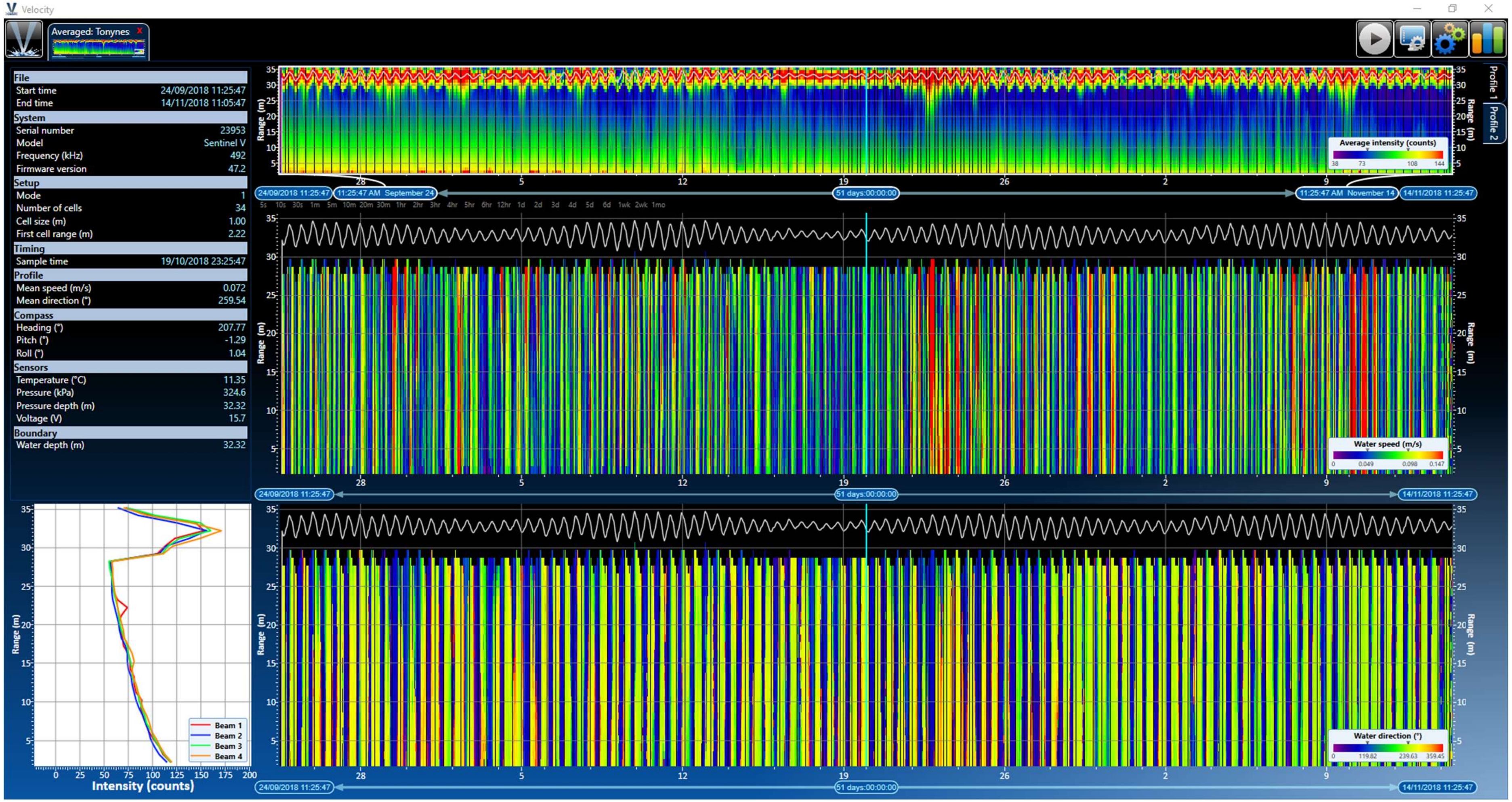
Appendix A Screenshot of *TOYNS000.000.pdv* from Teledyne's *Velocity* data processing software (entire dataset).



Appendix B	Plots of 'TOYNS' heading, pitch, roll, sensor depth, temperature and current velocity captured from *Velocity* data processing software (*TOYNS000.000.pdv*, entire dataset).



Appendix C Screenshot of *Toyness 20180924T112542.averaged.pdv* from Teledyne's *Velocity* data processing software (Profile 2).



Appendix D Plots of ‘Toyness’ heading, pitch, roll, sensor depth, temperature and current velocity captured from *Velocity* data processing software (*Toyness 20180924T112542.averaged.pdv, Profile 2*).