The Scottish Salmon Company

Hydrographic Report

North Arran, Firth of Clyde

Date	**06th October 2020**
Revision No.	**A2**
Author	
Approved by	

Table of Contents

Table of Figures

Table of Tables

1 Introduction

This report describes the methods used to collect hydrographic data at the proposed Scottish Salmon Company (SSC) North Arran fish farm and presents the outcomes of the survey exercise.

Three deployments were carried out at this location consecutively. All deployments were carried out by SSC, using a Teledyne RD Instruments Acoustic Doppler Current Profiler (ADCP) Workhorse, Sentinel V100 ADCP, mounted in a weighted seabed frame.

Analysis was carried out in accordance with the Scottish Environmental Protection Agency (SEPA) guidelines (Aquaculture Modelling - Regulatory Modelling Guidance for the Aquaculture Sector. Version 1.1, July 2019).

2 Site Description

The hydrographic survey site was located approximately 260 m north-east of the Isle of Arran. There were no pens on site at the time of the survey. Within the survey area, the seabed sloped eastwards to water depths greater than 50 m.

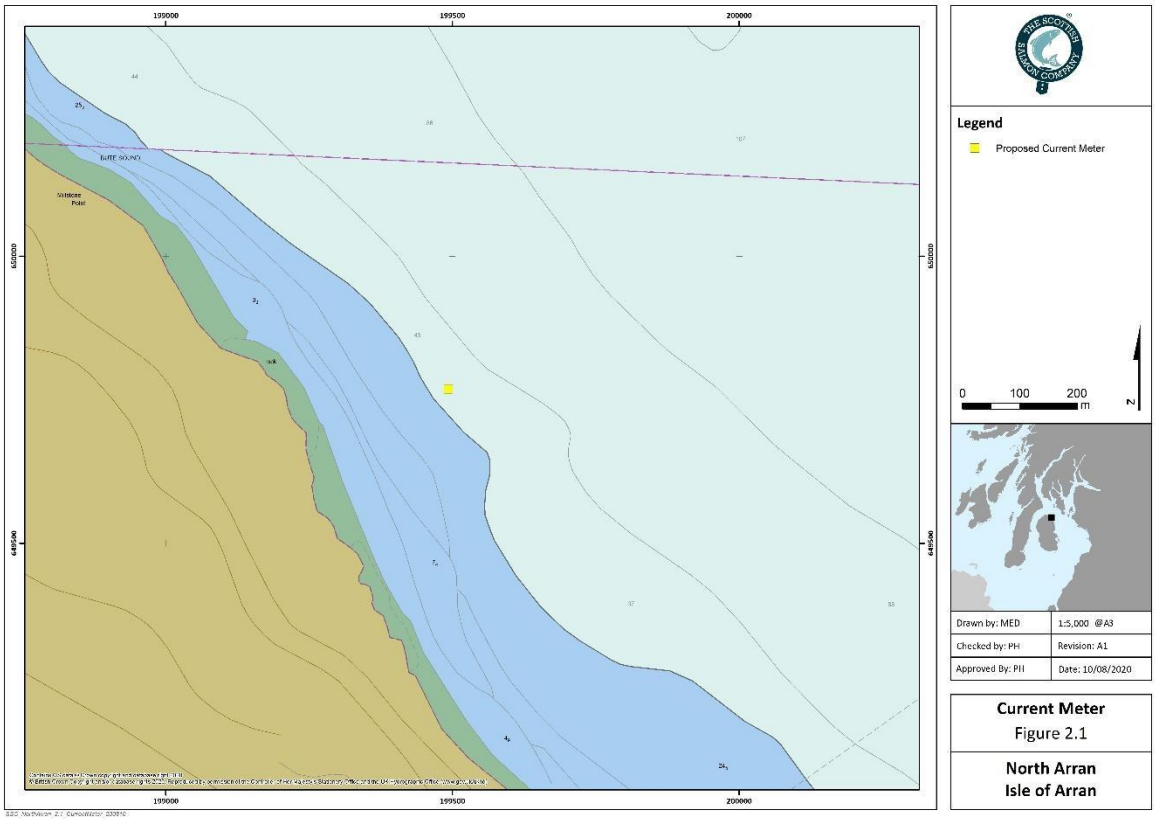

Figure 2.1. Location of the proposed North Arran site.

3 Materials and Methods

3.1 Bathymetry Survey

A full bathymetry survey was carried out using a Garmin portable chart plotter with acoustic sounder on 21st August 2018 (Figure 3.1). Boat GPS was used at the start of the survey to verify accuracy to return positional information (WGS84). Both devices received a minimum of eight satellite coverage throughout the survey. Recorded depths were corrected to Chart Datum (CD) using Admiralty Total Tide software and referenced against tide predictions for the secondary port Loch Ranza.

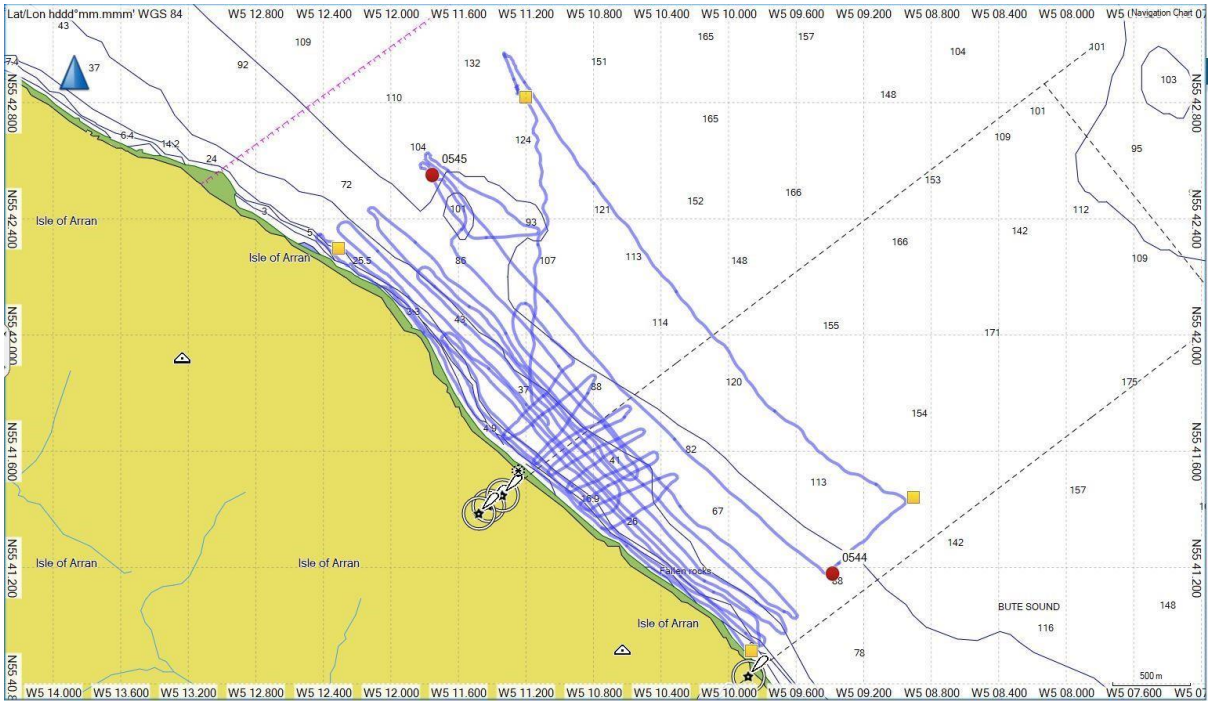

Figure 3.1. Bathymetry survey track for August 2018.

Surveyed bathymetric data was then combined with land form data and charted bathymetry from the survey area, to provide a comprehensive overview of bathymetry within the area around the potential fish farm location.

3.2 Current Meter Set-up

A Teledyne ADCP V100 was used to record current data at the North Arran site during three consecutive deployments. The current meter was installed in a mooring frame with 20° free gimbal movement that automatically levels the instrument when deployed on the seabed. The Sentinel V100 ADCP is a 300 kHz medium range, acoustic Doppler current profiler, which allows multiple, simultaneous sampling strategies with site specific cell size. This allows for current measurements throughout the water column, up to 100 m depths. Further information on this current meter can be accessed via the following link:

http://www.teledynemarine.com/adcps/marine-measurements

The ADCP was deployed on three occasions during 2020, in order to collect at least 90 days of current meter data. The first of these deployments was located at (WGS84) 55° 41.988' N 05° 11.560' W ((OSGB36) 199470E 649770N), the second deployment was located at (WGS84) 55° 41.979' N 05°11.542' W ((OSGB36) 199488E 649750N), and the third at (WGS84) 55° 41.988' N 05° 11.538' W ((OSGB36) 199493E 649769N). The deployment positions were approximately 20 m apart and within 150 m of the site centre. The average of the three deployment locations is as close as possible to the

nearest pen centre whilst being within 150 m from the site centre. These requirements are laid out by SEPA in Section 7 of the Regulatory Modelling Guidance for the Aquaculture Sector. The proposed location was accepted by SEPA on 18th June 2020. The transducer head was 60 cm from the base of the mooring frame.

Initial depth soundings were taken at the deployment site, in order to determine the depth the current would be situated at during high tide and in order for the appropriate cell size to be determined. The current meter was configured at the time of deployment, having established the water depth and expected tidal range on site.

3.3 Magnetic Variation

No magnetic variation correction was made to the current meter during the deployments, this was undertaken after the instrument was recovered and data downloaded. For the three deployments, a convergence value of -2.64° was applied. The grid magnetic angle applied to each deployment was 0.28°, 0.30° and 0.32°, respectively. This gave an overall declination of -2.36° for the first deployment, -2.34° for the second and -2.32° for the third and final deployment.

This was determined using the World Magnetic Model, produced jointly by the United States National Oceanographic and Atmospheric Administration's National Geophysical Data centre. Further details can be found at:

http://www.geomag.bgs.ac.uk/data_service/models_compass/wmm_calc.html

3.4 Data Processing

Data was downloaded and viewed using 'Velocity', a bespoke software for use with Teledyne instruments. Initial first checks were done on the data to determine if the deployments were successful. In particular, pitch and roll, and heading were analysed to confirm that the deployment was successful, with the instrument orientated upright, and no unexpected movement. From 'Velocity', the data was extracted to text files and then later further processed in Microsoft Excel and MATLAB.

SEPA specifies that data should be presented for specific depths, therefore the data was selected against the following requirements:

- Sub-surface: from a depth of 5m below the lowest predicted spring tide during the deployment period;
- Cage-bottom: at a depth corresponding to the bottom of the cages at mean sea level (+/- 1m);
- Near-bed: as close to the bed as predictable (<3m).

For all deployments, the near-bottom cell chosen was cell 1, giving a maximum height above the seabed of 2.59 m and a depth ranging from 20.95 m to 31.10 m. The cage-bottom and sub-surface cell for each deployment were calculated based on recorded depths. The calculated cell number and their depths are shown in **Error! Reference source not found.**.

Dataset		Near-bottom Cell	Cage-bottom Cell	Sub-surface Cell
North Arran 1	Cell Number	1	17	23

Dataset		Near-bottom Cell	Cage-bottom Cell	Sub-surface Cell
	Distance from seabed (m)	2.58	18.58	24.58
	Distance from surface (m)	27.75	9.77	3.77
North Arran 2	Cell Number	1	10	17
	Distance from seabed (m)	2.58	11.58	18.58
	Distance from surface (m)	20.96	9.97	2.97
North Arran 3	Cell Number	1	15	24
	Distance from seabed (m)	2.59	16.59	25.59
	Distance from surface (m)	26.20	10.2	1.20

The distance to the near-bed cell is automatically calculated based on the configuration settings of the instrument. This is the distance from the transducer to the centre of the first cell. This number is then added to the height of the transducer head from the seabed, to give the actual height of the centre of the first cell, which is within the remit of the SEPA criteria.

Once initial processing was completed, dataset 'stitching' was undertaken. This process reviewed Spring-Neap timelines for each of the datasets and matched the end of one dataset to the start of the next dataset, based on where in the tidal cycle the dataset started/finished on. This process has taken into account the 12.42 hr tidal cycle, therefore there is minimal mismatch between high and low tide. The important factor in 'stitching' data together is to match the Spring-Neap cycles.

4 Results and Discussion

4.1 Bathymetry Survey

Bathymetric data was gathered in August 2018 using a Garmin chart plotter. This data was used to validate Admiralty chart data for the area. The survey concluded that chart data was reliable throughout the development area. A combination of the collected depth data and Admiralty chart data was used to represent the bathymetry around the North Arran site (Figure 4.1). The mean depth for the 2 x 2 km area was 45.65 m.

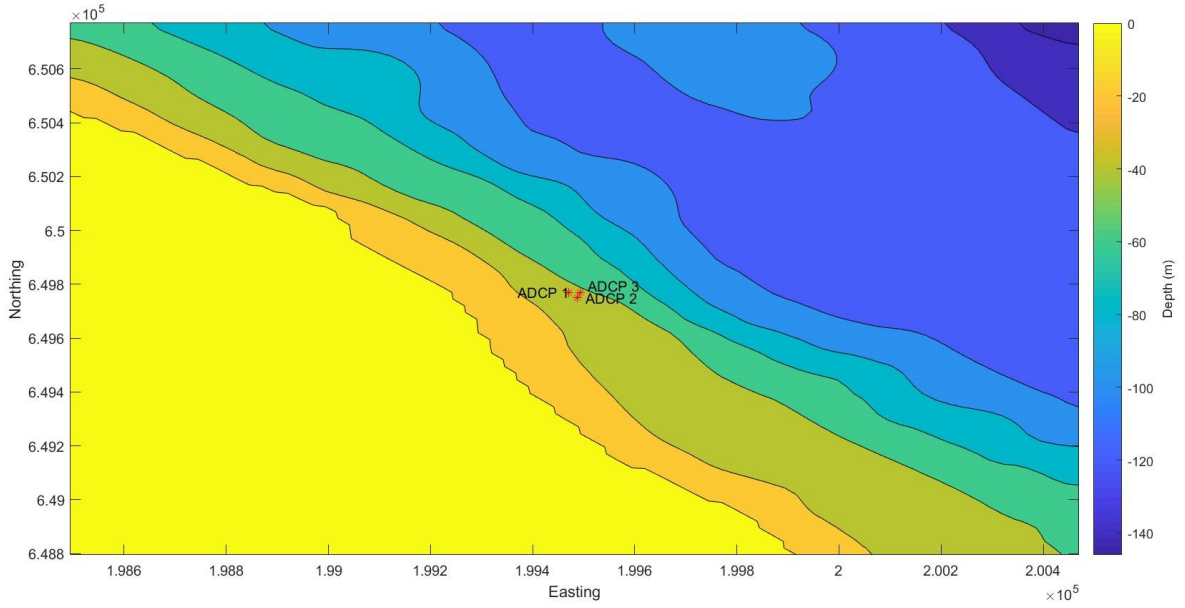

Figure 4.1. Representation of bathymetry in a 2 x 2 km grid around the proposed North Arran site, taken from Admiralty charts and the August 2018 survey. The current meter locations are shown (ADCP).

4.2 Current Data

During the initial processing stages, heading, pitch and roll were analysed to ensure the deployments were successful, presented in Table 1 and Figure 4.2 to Figure 4.4**Error! Reference source not found.**. These values are within the accepted range for successful deployments.

Table 1. Pitch, roll and heading range for all three North Arran deployments.

	Pitch (°)	Roll (°)	Heading (°)
North Arran 1	0.39	0.42	8.23
North Arran 2	0.23	0.19	6.56
North Arran 3	0.15	0.25	4.30

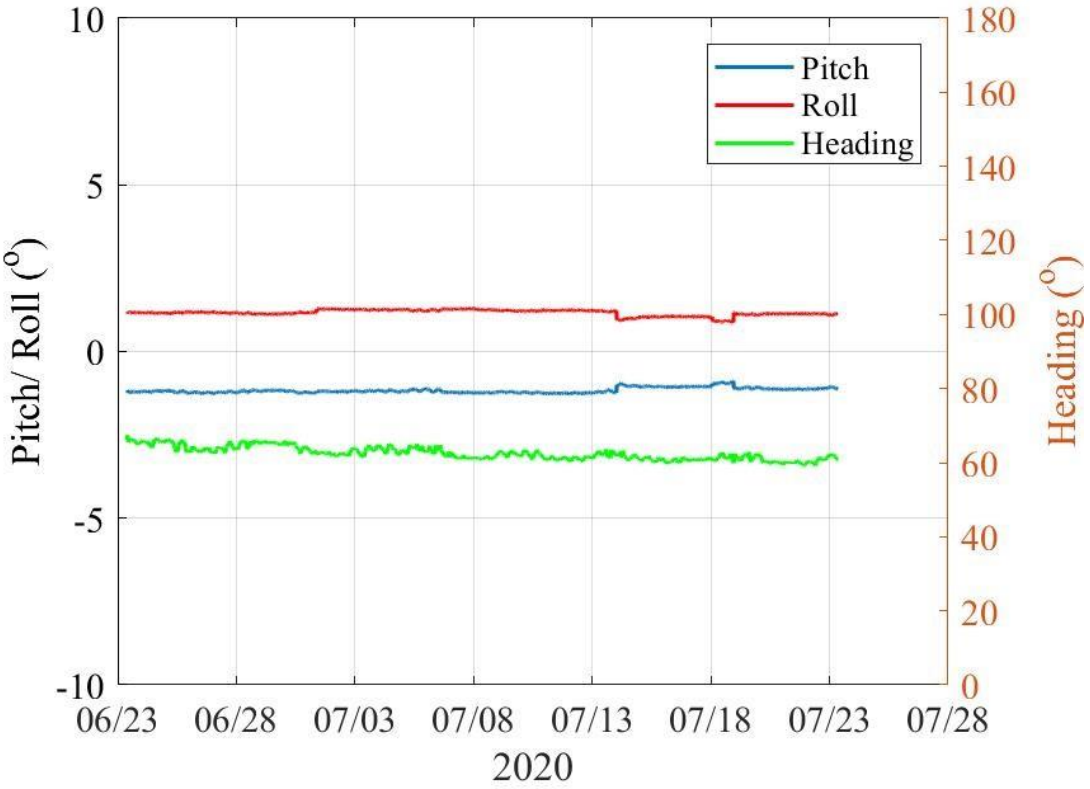

Figure 4.2. Heading, pitch and roll for North Arran deployment from 23rd June 2020 – 23rd July 2020.

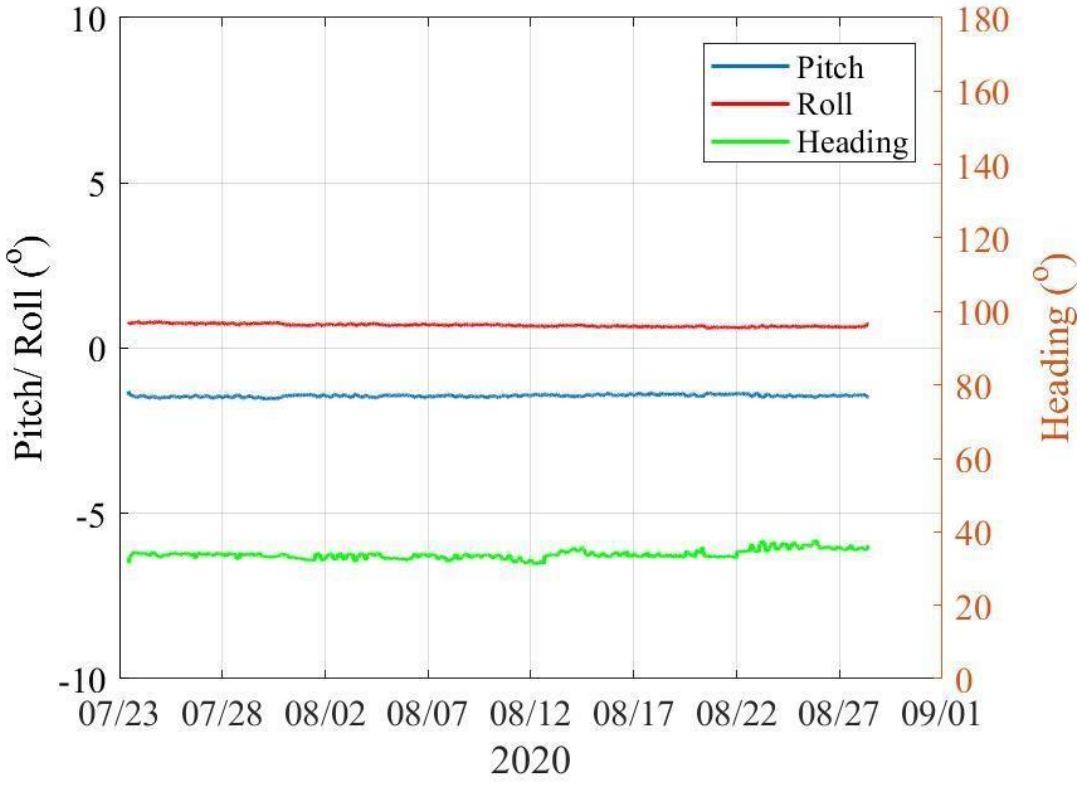

Figure 4.3. Heading, pitch and roll for North Arran deployment from 23rd July 2020 – 28th August 2020.

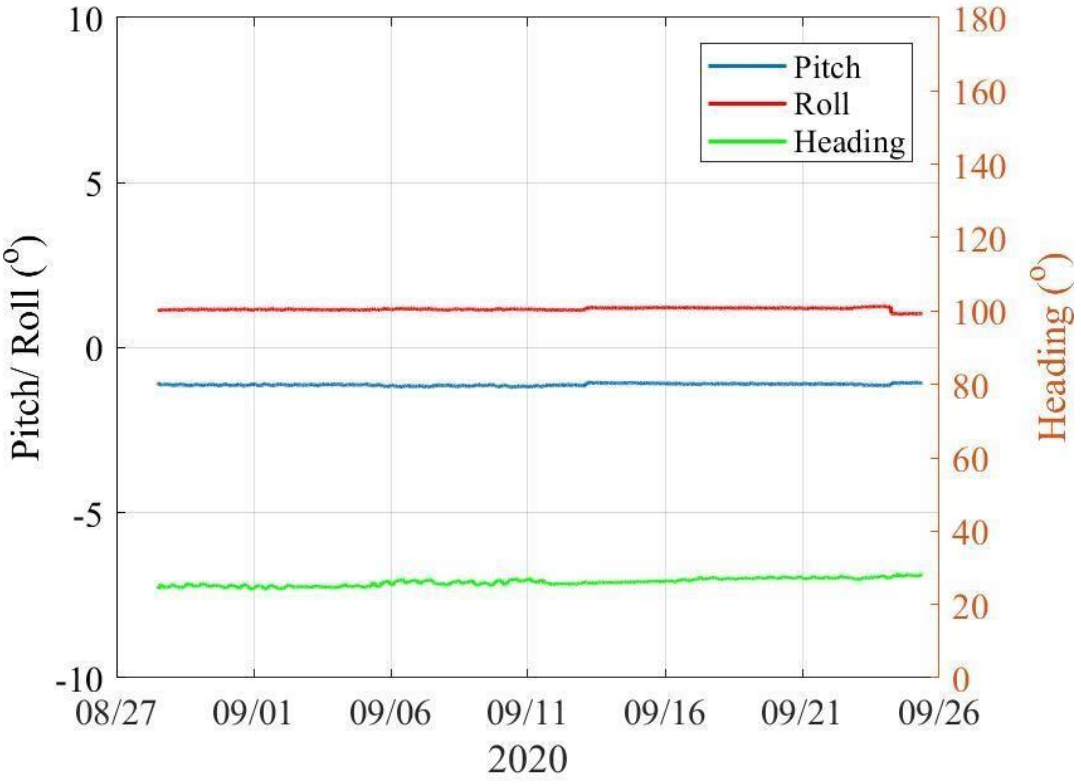

Figure 4.4. Heading, pitch and roll for North Arran deployment from 28th August 2020 – 25th September 2020.

A summary of the current data is shown in Appendix 1 and of the SEPA HG analysis spreadsheets in Appendix 2.

The data collected was consecutive, meaning data 'stitching' was straightforward. Data was 'stitched' together in such a way as to minimise error between Spring-Neap cycles. Table 2 shows the datasets and their Spring-Neap cycle, in the order in which they were 'stitched' together. To fill the hour gaps between the datasets, the velocity and direction data has been selected from the appropriate time in the Spring-Neap cycle and replicated.

Table 2. North Arran current meter tidal cycles.

Dataset	Start	Tide	Spring Time (days)	End	Tide	Spring Time (days)
North Arran 1	23/06/2020 09:30	2.5 hours after low	0	23/07/2020 08:30	1.5 hours after low	1 after
Fill gap	08/07/2020 09:10	1.5 hours after low	1 after	08/07/2020 11:10	3.5 hours after low	1 after
North Arran 2	23/07/2020 10:35	3.5 hours after low	1 after	28/08/2020 09:55	3 hours after high	7 before
Fill gap	12/09/2020 09:44	3 hours after high	7 before	12/09/2020 13:04	1 hour before low	7 before

Dataset	Start	Tide	Spring Time (days)	End	Tide	Spring Time (days)
North Arran 3	28/08/2020 12:24	1 hour before low	7 before	25/09/2020 09:04	3 hours before low	6 after

A summary of the current data is shown in Table 3 to

	Mean Speed (cm/s)	Residual Speed (cm/s)	Residual direction °T	Major axis °T
Sub-surface	11.7	2.7	132	145
Cage bottom	10.4	4.8	142	145
Near-bed	7.0	4.0	147	150

Table 5. In Dataset 1, the sub-surface, cage-bottom and near-bed cells had averages of 11.6 cm/s, 10.7 cm/s and 8.8 cm/s respectively. This gave an overall average of 10.4 cm/s. Within Dataset 2, the subsurface, cage-bottom and near-bed cells had averages of 11.7 cm/s, 10.4 cm/s and 7.0 cm/s respectively. This gave an overall average of 9.7 cm/s. Finally, in Dataset 3, the sub-surface, cagebottom and near-bed cells had averages of 11.4 cm/s, 9.1 cm/s and 7.8 cm/s respectively. This gave an overall average of 9.4 cm/s. The orientation of the velocities for all the deployments was on a northwest to south-east axis, consistent with a parallel flow to the shoreline.

The mean residual currents for the sub-surface, cage-bottom and near-bed cells are 2.6 cm/s, 2.8 cm/s and 5.6 cm/s for Dataset 1, with an overall average of 3.6 cm/s; 2.7 cm/s, 4.8 cm/s and 4.0 cm/s for dataset 2, with an overall average of 3.8 cm/s; and 2.8 cm/s, 0.4 cm/s and 3.7 cm/s for Dataset 3, with an overall average of 2.3 cm/s. Similar to the combined velocity, the direction of the residual current at all depths was along the north-west to south-east axis. The residual currents recorded during the deployment indicate that there is little wind influence at the cage bottom and sub-surface cells, and tidal flow is the dominant flow at these depths. There is an increased residual flow at the near bed cell which may be induced by shoreline related currents.

Table 3 Summary of currents recorded at North Arran Dataset 1.

	Mean Speed (cm/s)	Residual Speed (cm/s)	Residual direction °T	Major axis °T
Sub-surface	11.6	2.6	144	150
Cage bottom	10.7	2.8	147	150
Near-bed	8.8	5.6	142	150

Table 4 Summary of currents recorded at North Arran Dataset 2.

	Mean Speed (cm/s)	Residual Speed (cm/s)	Residual direction °T	Major axis °T
Sub-surface	11.7	2.7	132	145
Cage bottom	10.4	4.8	142	145
Near-bed	7.0	4.0	147	150

Table 5 Summary of currents recorded at North Arran Dataset 3.

	Mean Speed (cm/s)	Residual Speed (cm/s)	Residual direction °T	Major axis °T
Sub-surface	11.4	2.8	327	315
Cage bottom	9.1	0.4	316	315
Near-bed	7.8	3.7	125	130

The depth records shown by the current meter pressure sensor cells corresponded to the rise and fall of the tide, as checked with Total Tide software for the deployment periods; high and low tides corresponded with small variations of +/- 9 minutes.

The SEPA HG analysis spreadsheet for the 94 days of current data is shown in Appendix 2. The subsurface, cage-bottom and near-bed cells had averages of 11.6 cm/s, 10.1 cm/s and 7.9 cm/s respectively. This gave an overall average of 9.9 cm/s. The orientation of the velocities was southeast at all three cells. Similar to the individual deployments this orientation of the flow is parallel to the shoreline. The mean residual currents for the sub-surface, cage-bottom and near-bed cells were 1.0 cm/s, 2.6 cm/s and 4.3 cm/s, with an overall average of 2.6 cm/s. The direction of the residual current at all depths was also southeast at all three cells.

5 Summary of Meteorological Data

SEPA have determined that meteorological data is no longer required in the assessment of site hydrographic conditions, due to the use of 90+ days of current meter data. This longer deployment schedule is achieved through multiple deployments, an extended time period and will likely represent different seasons of the year. This provides a more realistic representation of conditions experienced at the site, compared with the previous methodology of short current meter deployments. Through post-processing, the current data has been used to analyse full flow and tide only flow conditions for the deployment periods, thus assessing the influence of meteorological conditions on the site.

6 Conclusion

Bathymetry and hydrographic data have been collected at the proposed North Arran site. The results from three deployments, totalling 94 days of data collection, have been presented in this hydrographic report. Due to the successful deployments and good quality of data, these measurements are believed to be reliable and representative of the location of the site.

Overall, the recorded data are indicative of a moderately flushed site and are considered suitable for further use in modelling. These datasets are considered to provide a good basis for hydrodynamic and bath treatment modelling.

Meteorological data was not collected.

7 Appendices

7.1 Appendix 1: Summary of current meter data for North Arran deployment

Table 1. Summary of currents recorded at North Arran 1.

No. of records	2158		
Start date / time	23/06/2020 09:30		
End date / time	23/07/2020 08:30		
	Near-bed	**Cage-bottom**	**Sub-surface**
Cell Number	1	17	23
Mean speed (m/s)	0.088	0.107	0.116
Residual speed (m/s)	0.056	0.028	0.026
Residual direction °T	142	147	144
Major axis °T	150	150	150
Residual parallel (m/s)	0.055	0.028	0.026
Residual normal (m/s)	-0.007	-0.002	-0.003
Amplitude parallel (m/s)	0.118	0.173	0.191
Amplitude normal (m/s)	0.033	0.040	0.041
Resuspension Threshold (9.5cm/s)	41%	48%	53%

Table 2. Summary of currents recorded at North Arran 2.

No. of records	2591		
Start date / time	23/07/2020 10:35		
End date / time	28/08/2020 09:55		
	Near-bed	**Cage-bottom**	**Sub-surface**
Cell Number	1	10	17
Mean speed (m/s)	0.070	0.104	0.117
Residual speed (m/s)	0.040	0.048	0.027
Residual direction °T	147	142	132
Major axis °T	150	145	145
Residual parallel (m/s)	0.040	0.048	0.026
Residual normal (m/s)	-0.002	-0.002	-0.006
Amplitude parallel (m/s)	0.100	0.163	0.200

Amplitude normal (m/s)	0.033	0.034	0.038
Resuspension Threshold (9.5cm/s)	26%	45%	49%

Table 3. Summary of currents recorded at North Arran 3.

No. of records	2007		
Start date / time	28/08/2020 12:24		
End date / time	25/09/2020 09:04		
	Near-bed	**Cage-bottom**	**Sub-surface**
Cell Number	1	15	24
Mean speed (m/s)	0.078	0.091	0.114
Residual speed (m/s)	0.037	0.004	0.028
Residual direction °T	125	316	327
Major axis °T	130	315	315
Residual parallel (m/s)	0.037	0.004	0.027
Residual normal (m/s)	-0.004	0.000	0.006
Amplitude parallel (m/s)	0.113	0.153	0.186
Amplitude normal (m/s)	0.036	0.039	0.046
Resuspension Threshold (9.5cm/s)	32%	38%	50%

7.2 Appendix 2: HG analysis spreadsheets for the North Arran deployments.

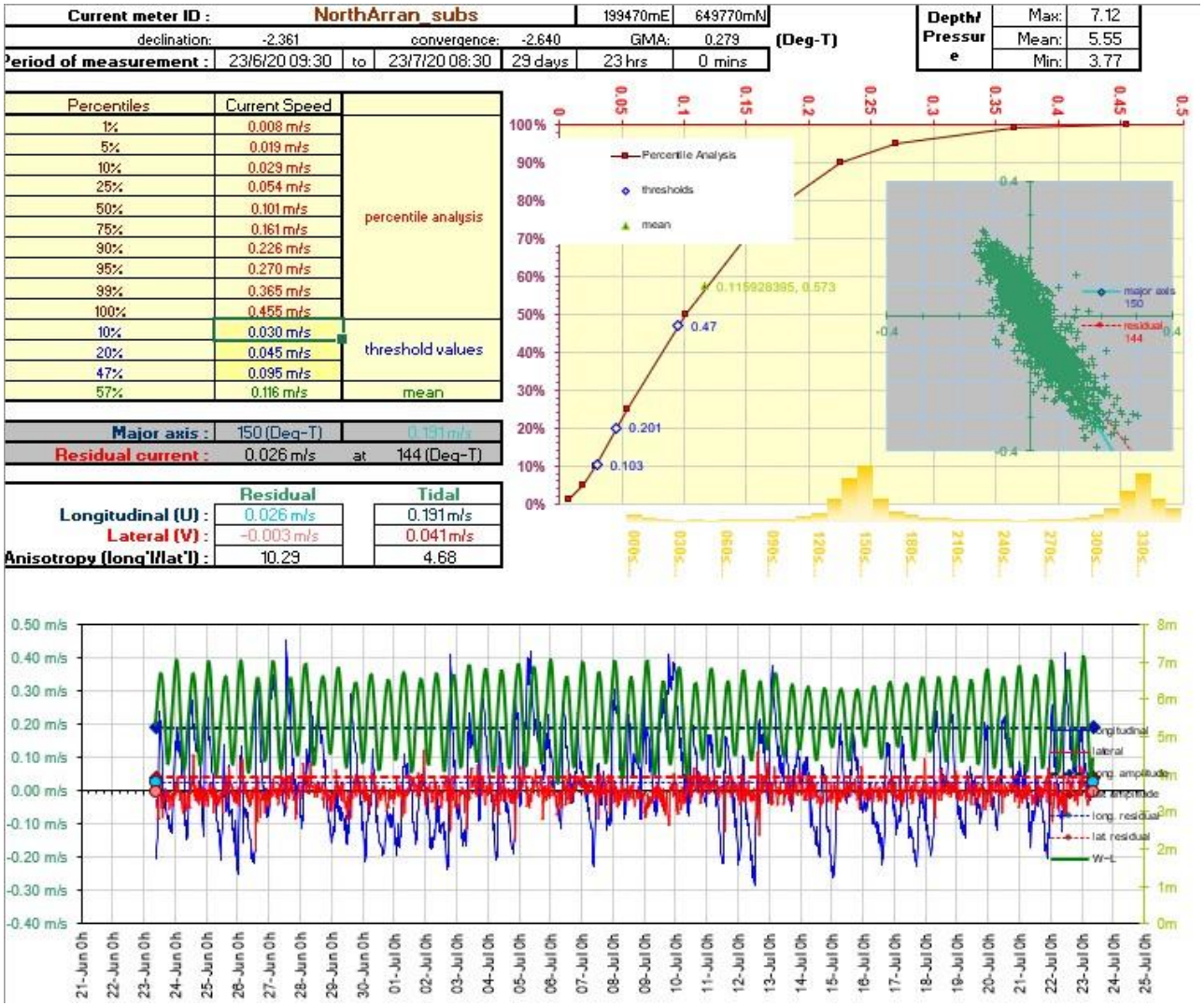

Figure 7.1. HG analysis summary of the sub-surface cell for North Arran 1.

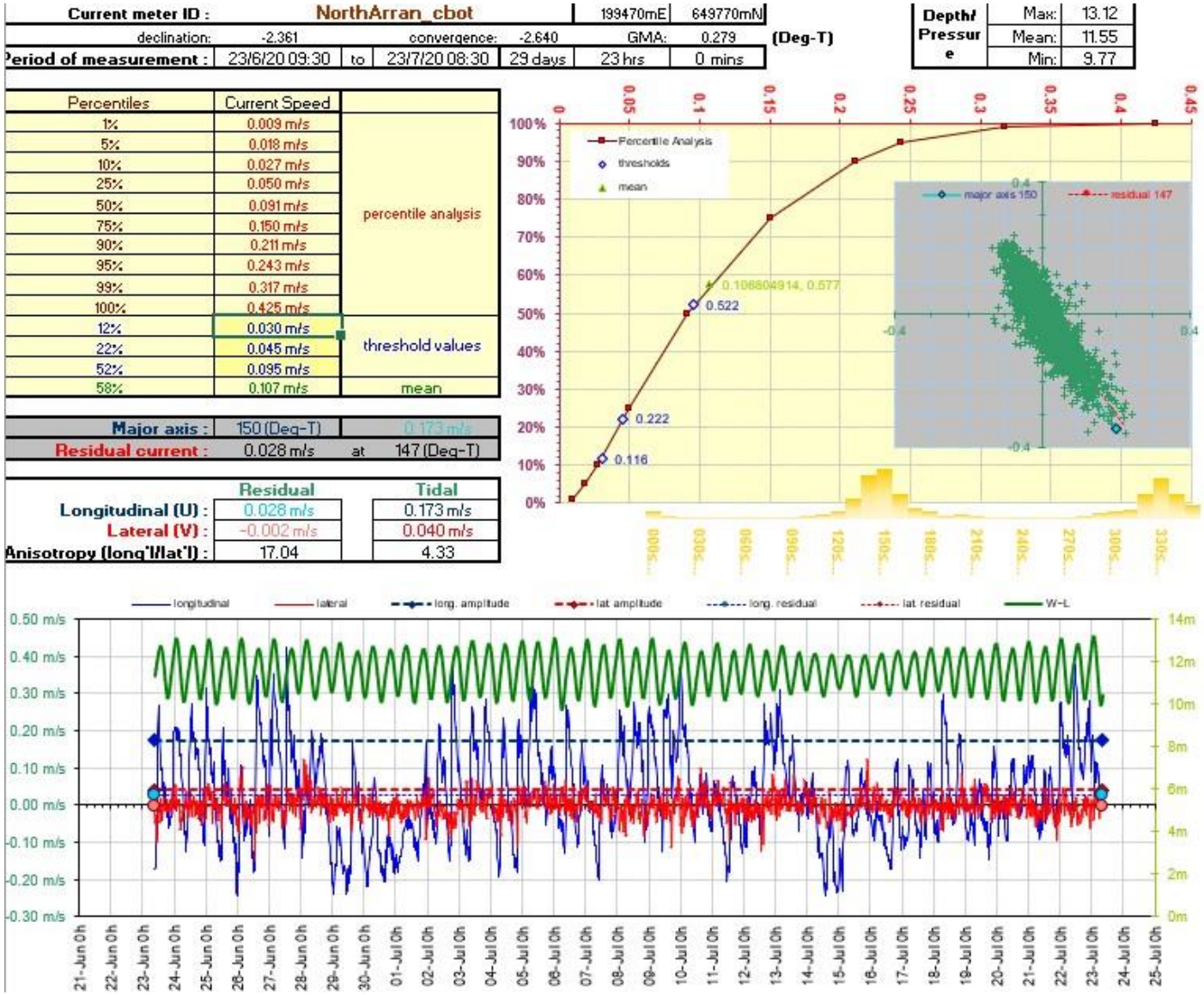

Figure 7.2. HG analysis summary of the cage-bottom cell for North Arran 1.

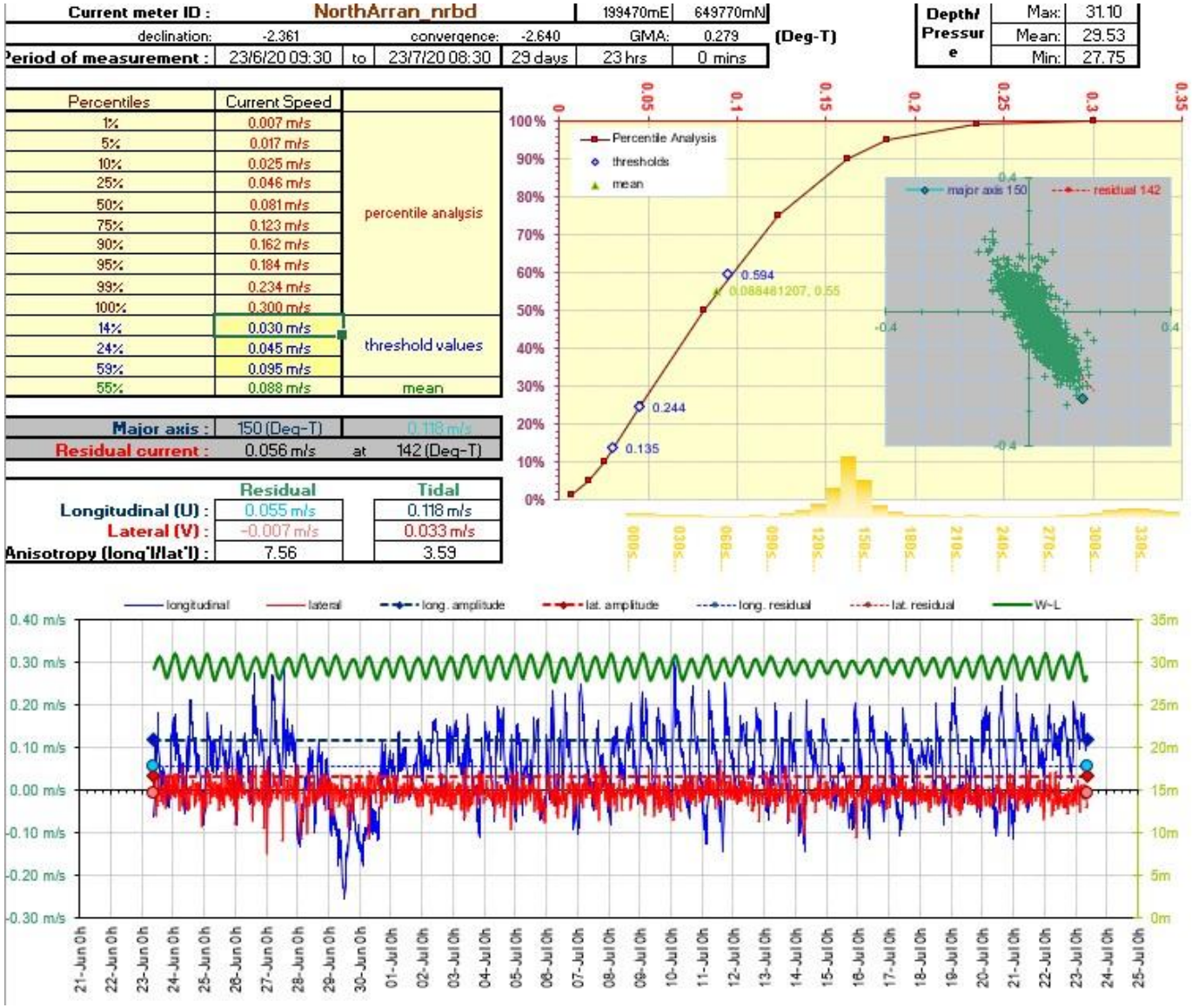

Figure 7.3. HG analysis summary of the near-bed cell for North Arran 1.

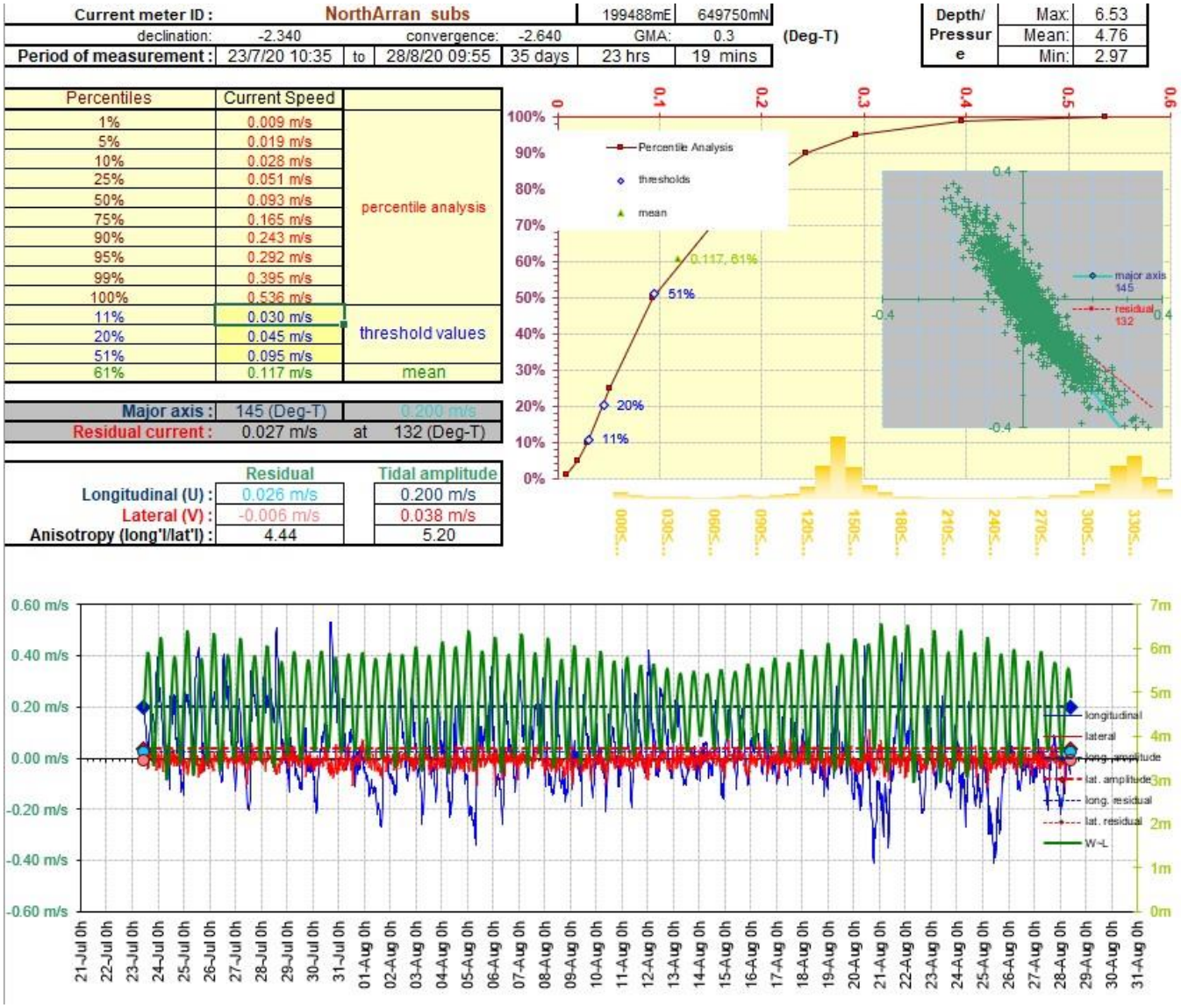

Figure 7.4 HG analysis summary of the sub-surface cell for North Arran 2.

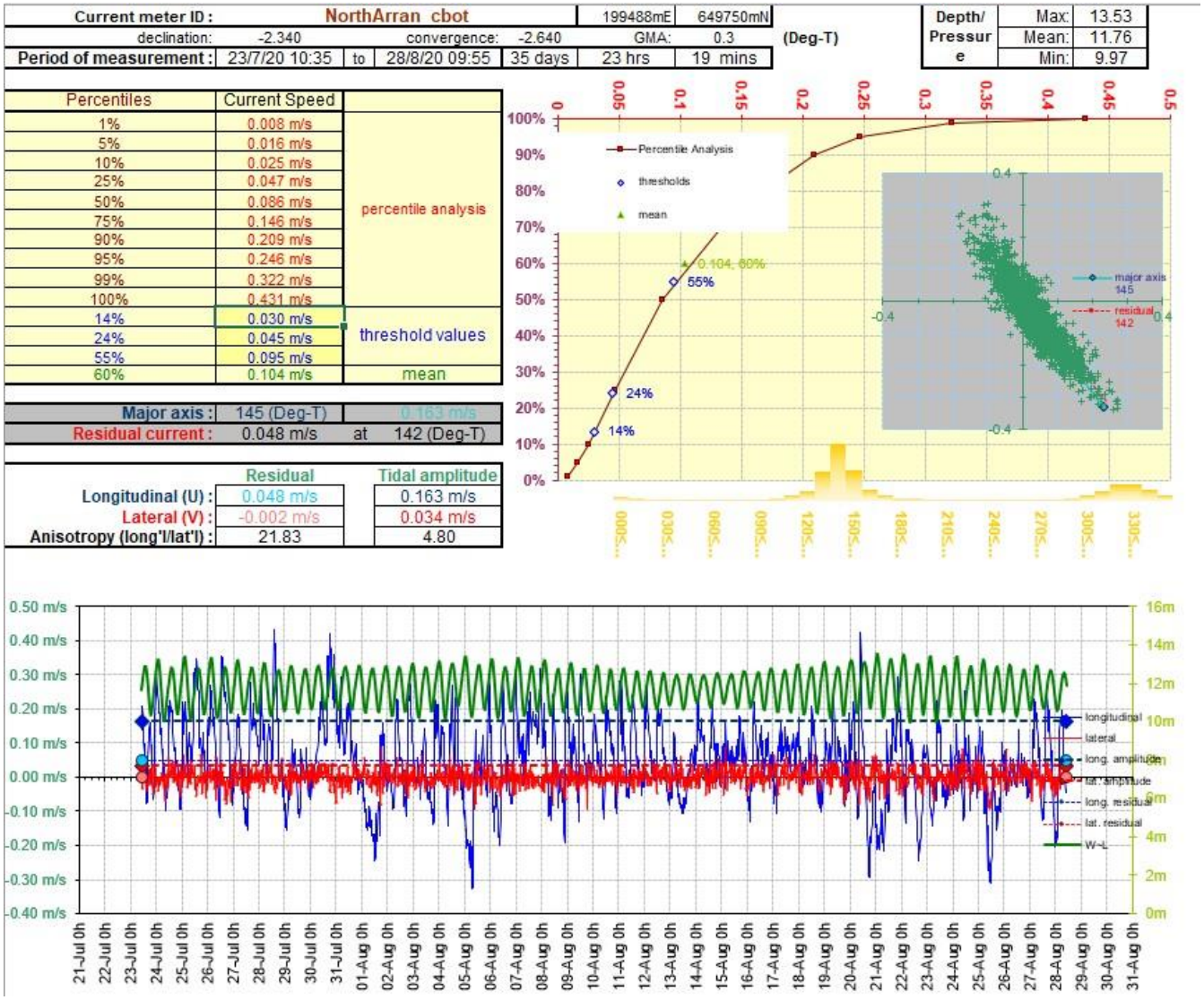

Figure 7.5 HG analysis summary of the cage bottom cell for North Arran 2.

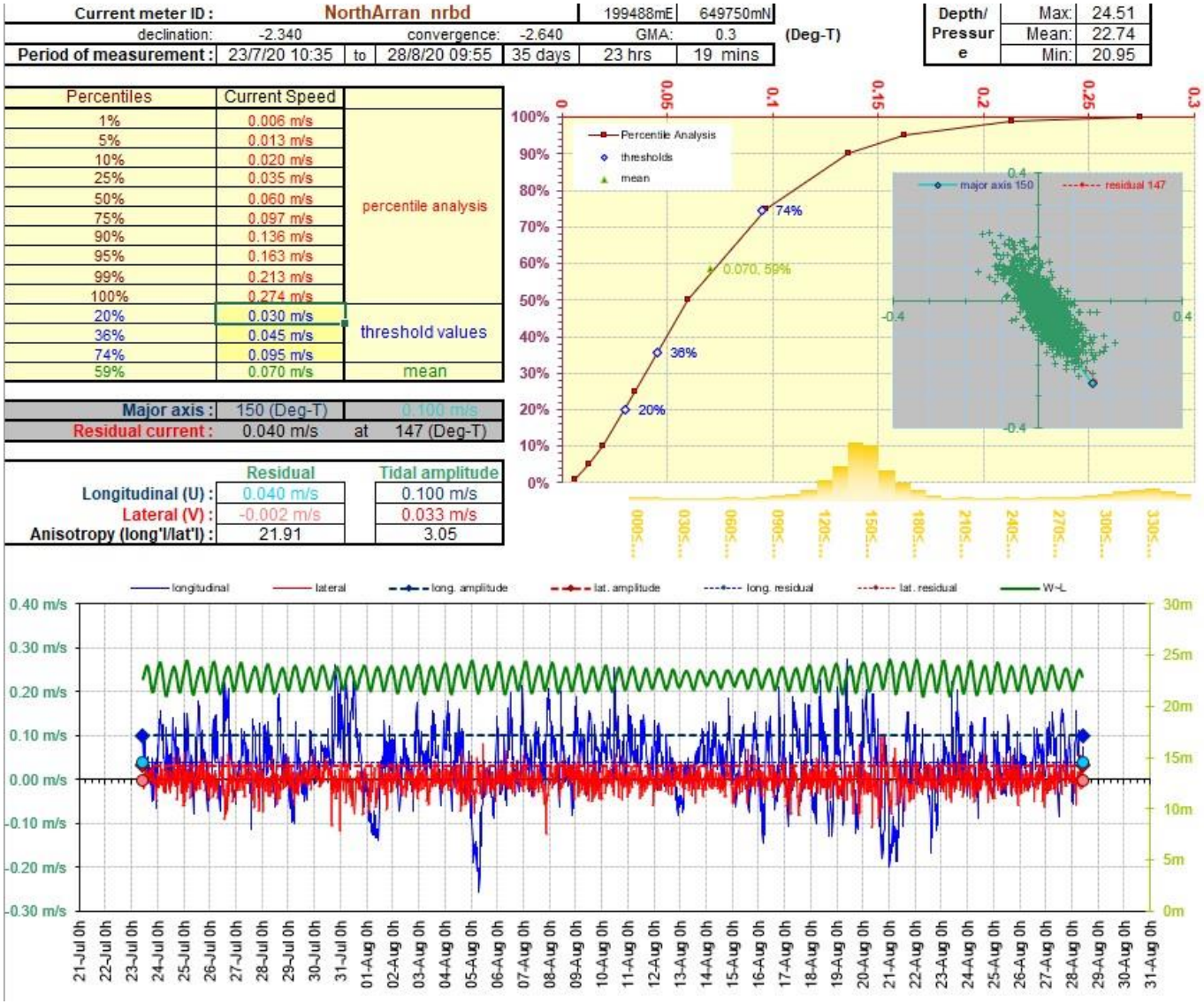

Figure 7.6 HG analysis summary of the near-bed cell for North Arran 2.

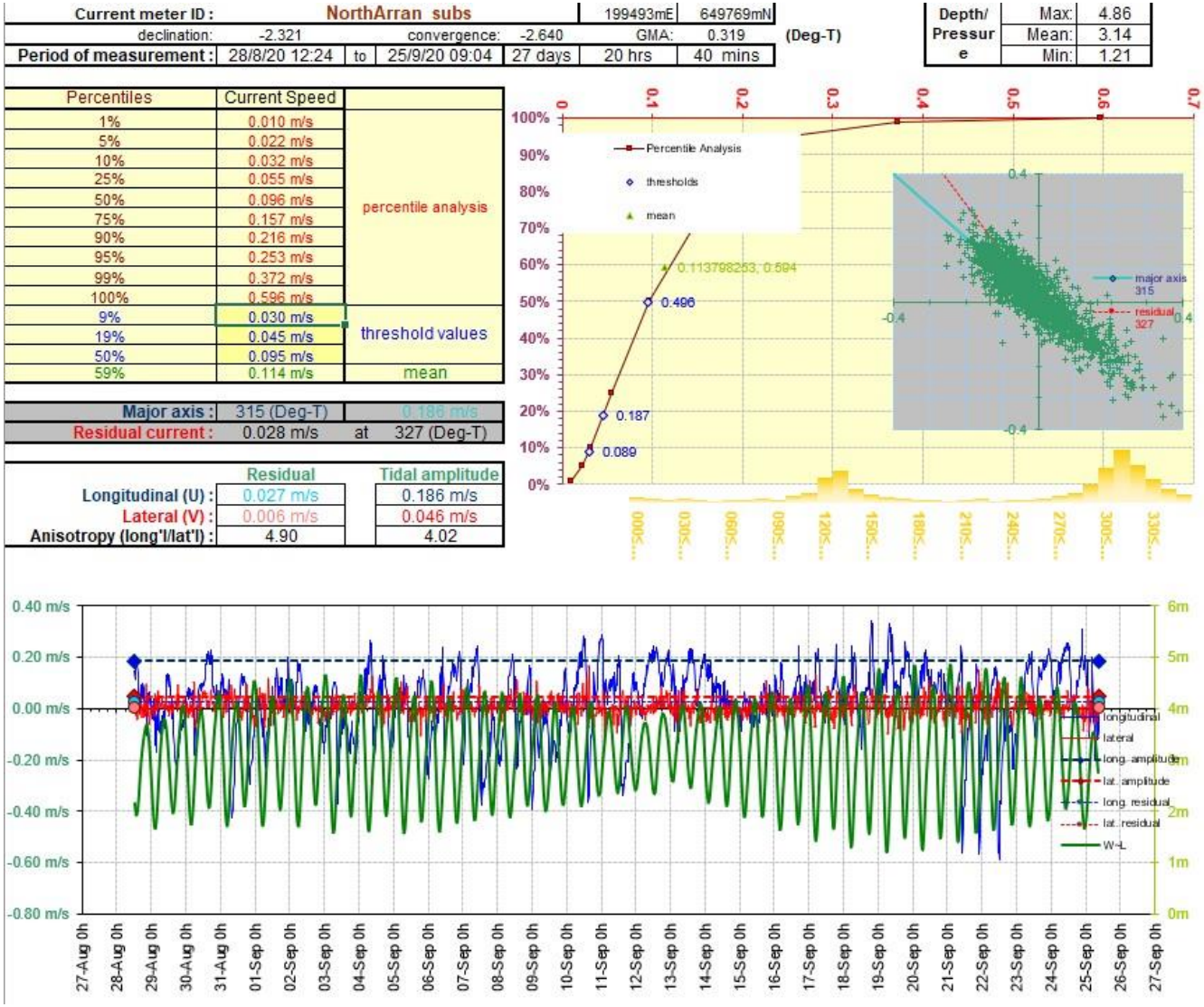

Figure 7.7 HG analysis summary of the sub-surface cell for North Arran 3.

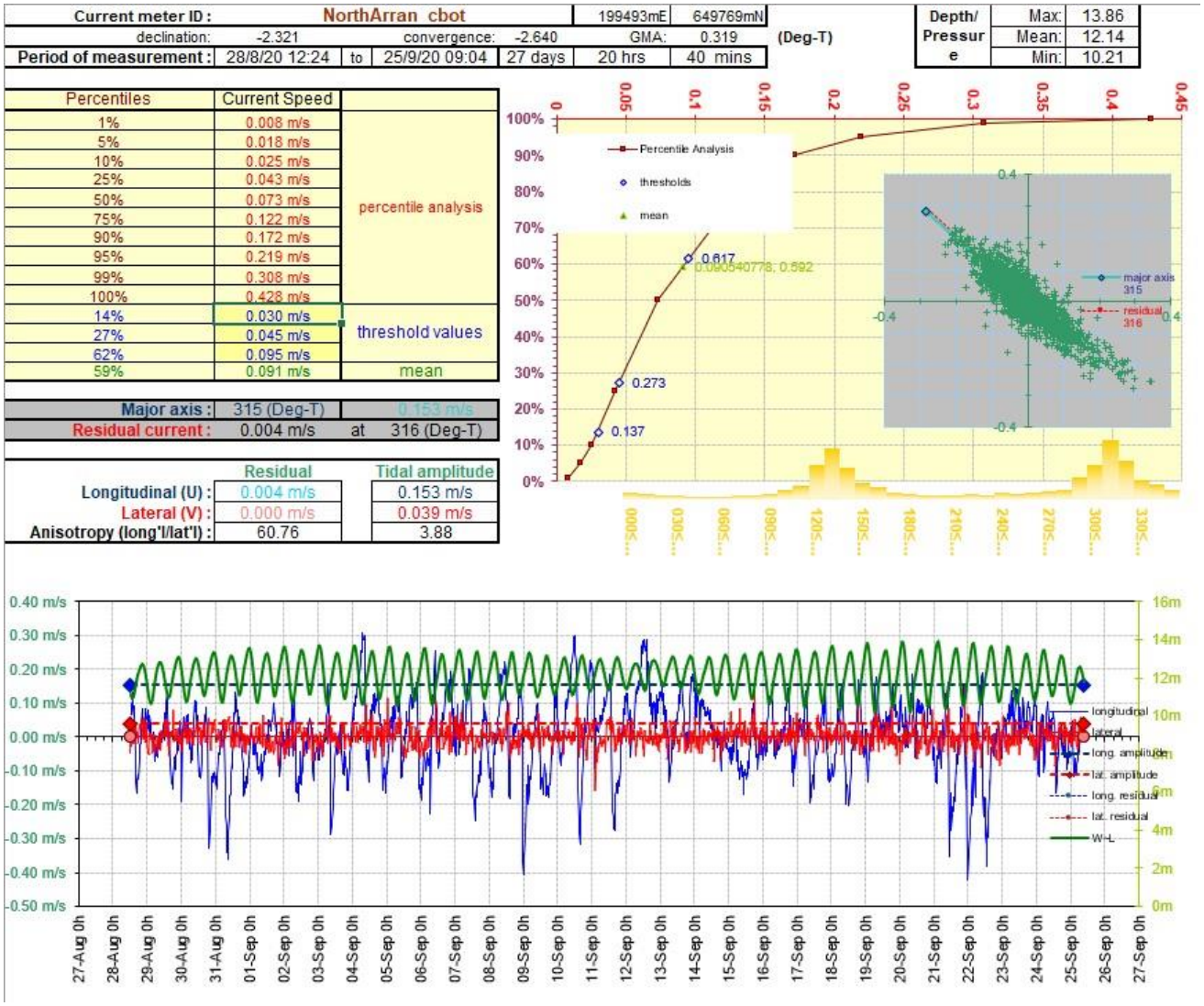

Figure 7.8 HG analysis summary of the cage bottom cell for North Arran 3.

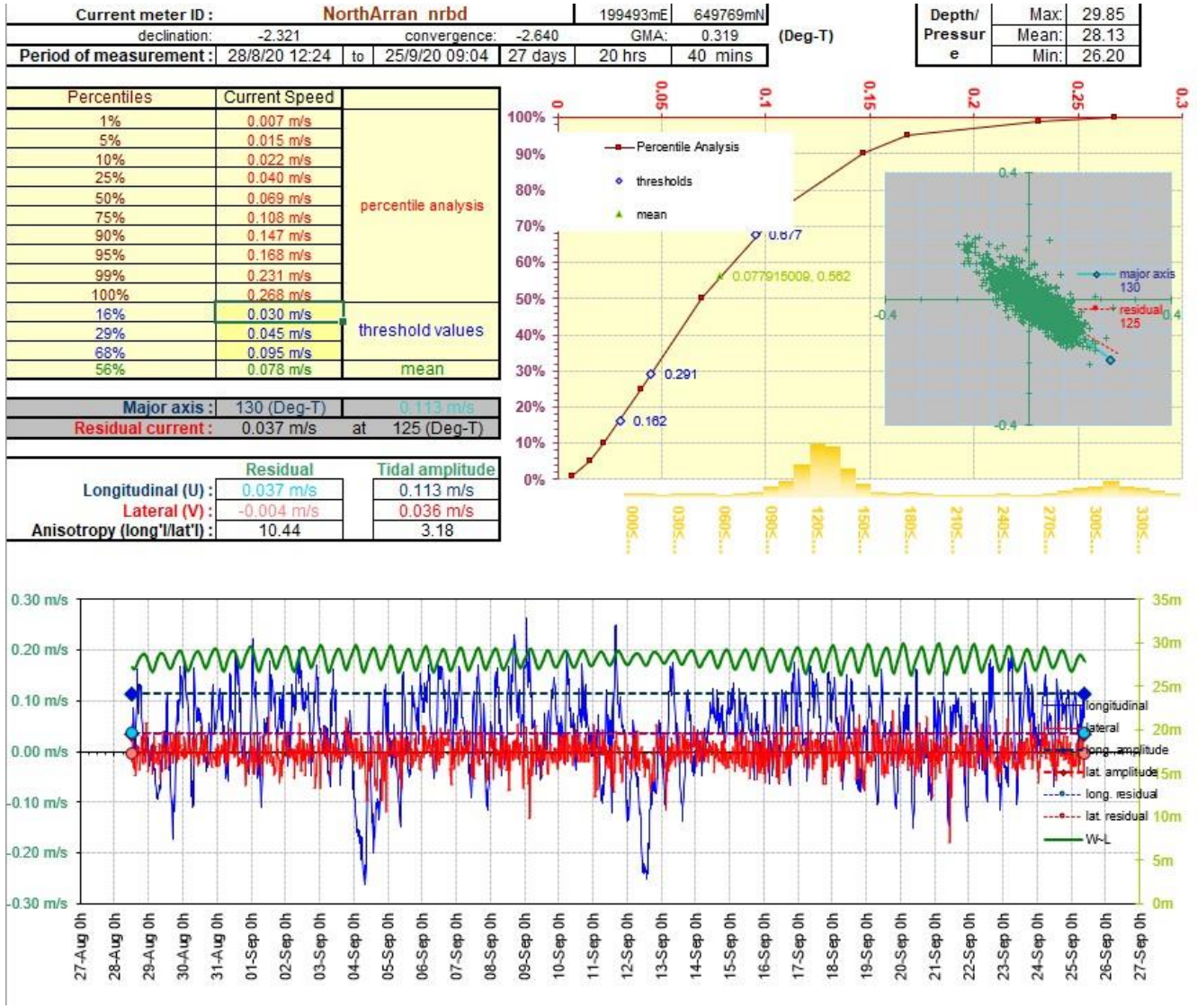

Figure 7.9 HG analysis summary of the near-bed cell for North Arran 3.

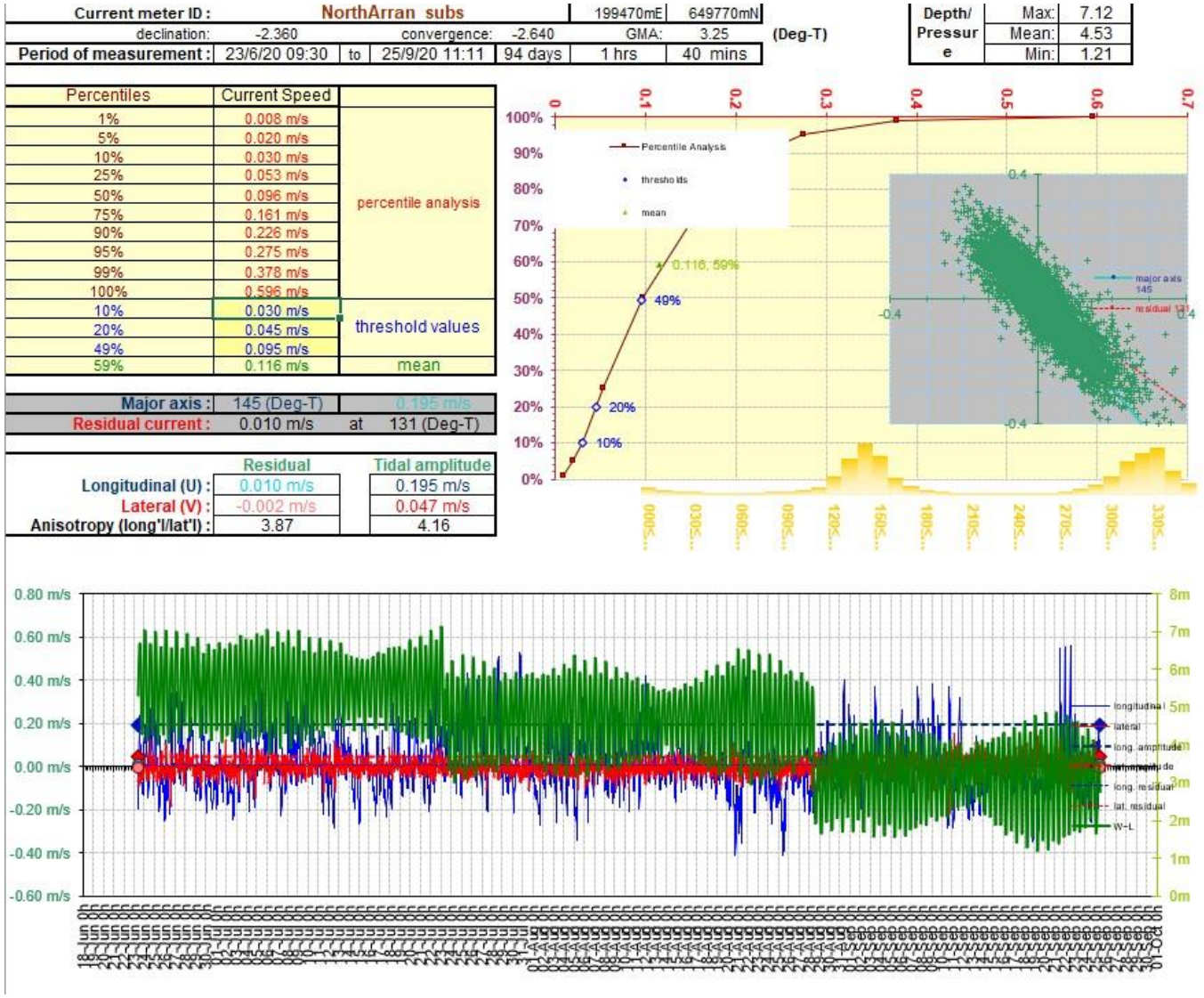

Figure 7.10. HG analysis summary of the sub-surface cell for North Arran 94-days.

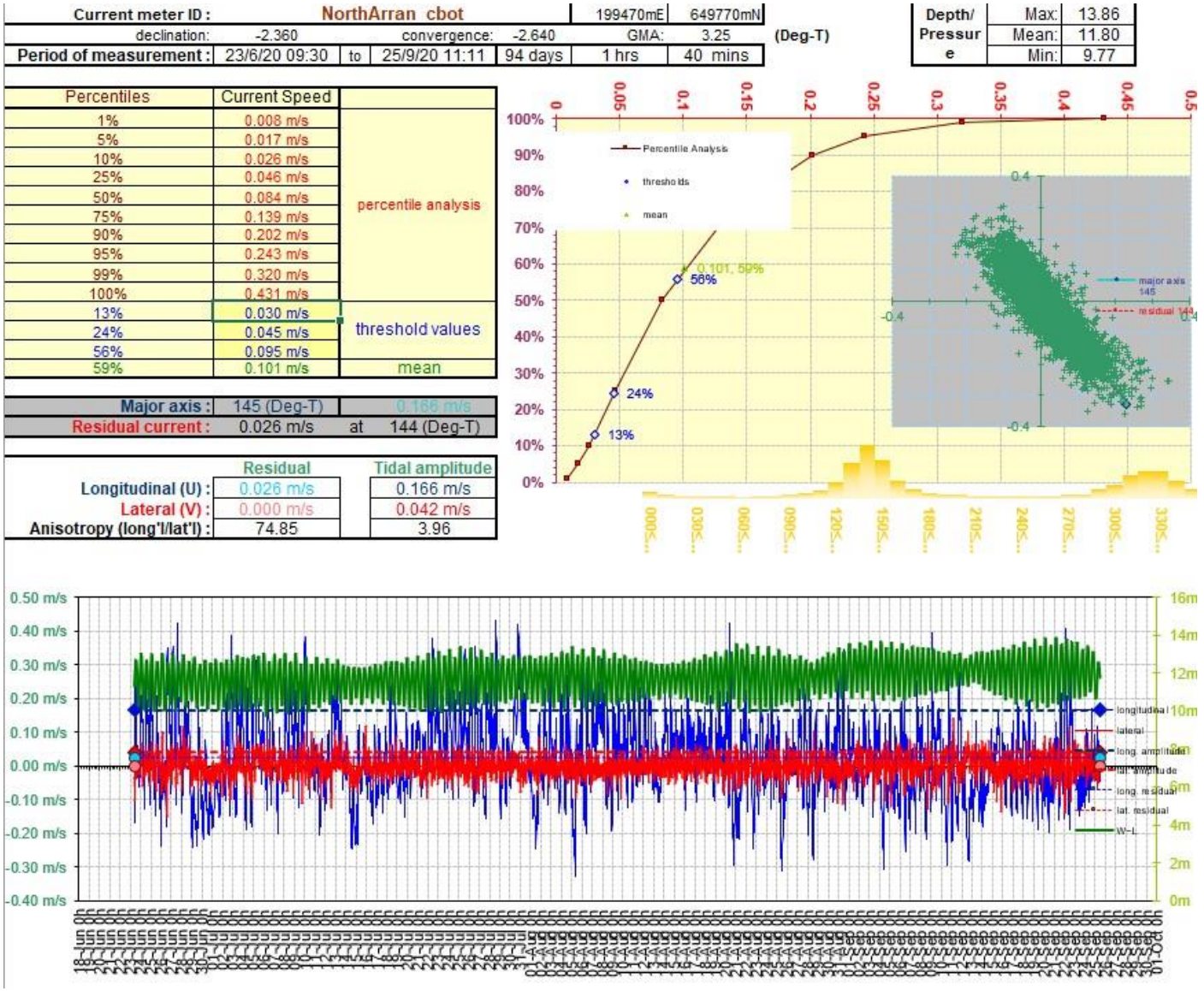

Figure 7.11. HG analysis summary of the cage bottom cell for North Arran 94-days.

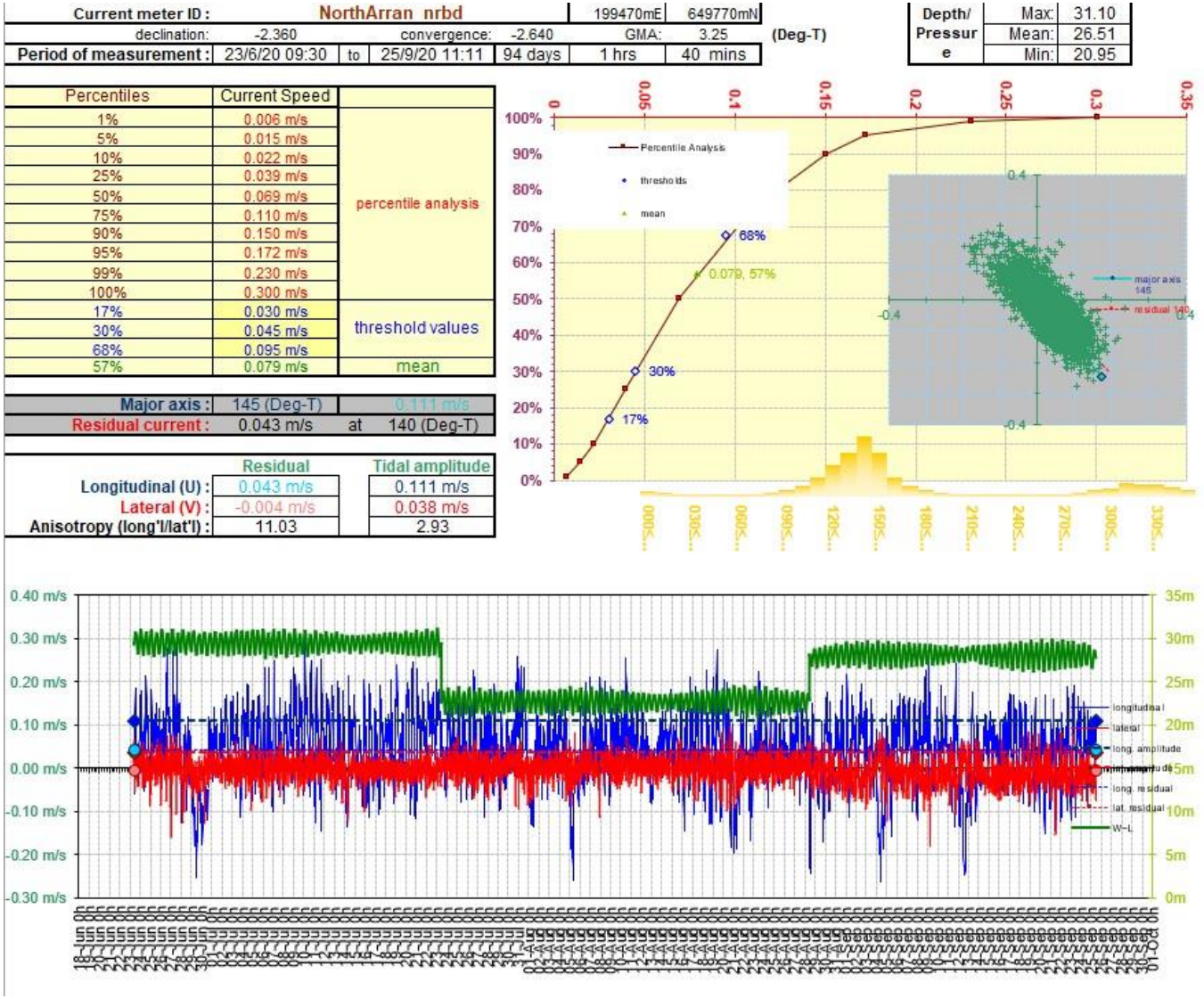

Figure 7.12. HG analysis summary of the near-bed cell for North Arran 94-days.