BAKKAFROST

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SCOTLAND

Hydrographic Report

North Gravir, Isle of Lewis

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Introduction

This report describes the methods used to collect hydrographic data at the proposed Bakkafrost Scotland (BFS) North Gravir fish farm and presents the outcomes of the survey exercise.

This deployment was carried out by BFS, using a Teledyne RD Instruments Acoustic Doppler Current Profiler (ADCP) Workhorse, mounted in a weighted seabed frame.

Analysis was carried out in accordance with the Scottish Environmental Protection Agency (SEPA) guidelines (Hydrographic Data Guidance For Aquaculture- February 2022, and Interim New Depomod Guidance Draft- April 2022).

Site Description

The hydrographic survey site was located approximately 1.6 km north of Loch Odhairn, Isle of Lewis (Figure 0.1). There were no pens on site at the time of the survey. Within the survey area, the seabed slopes eastwards to water depths greater than 100 m.

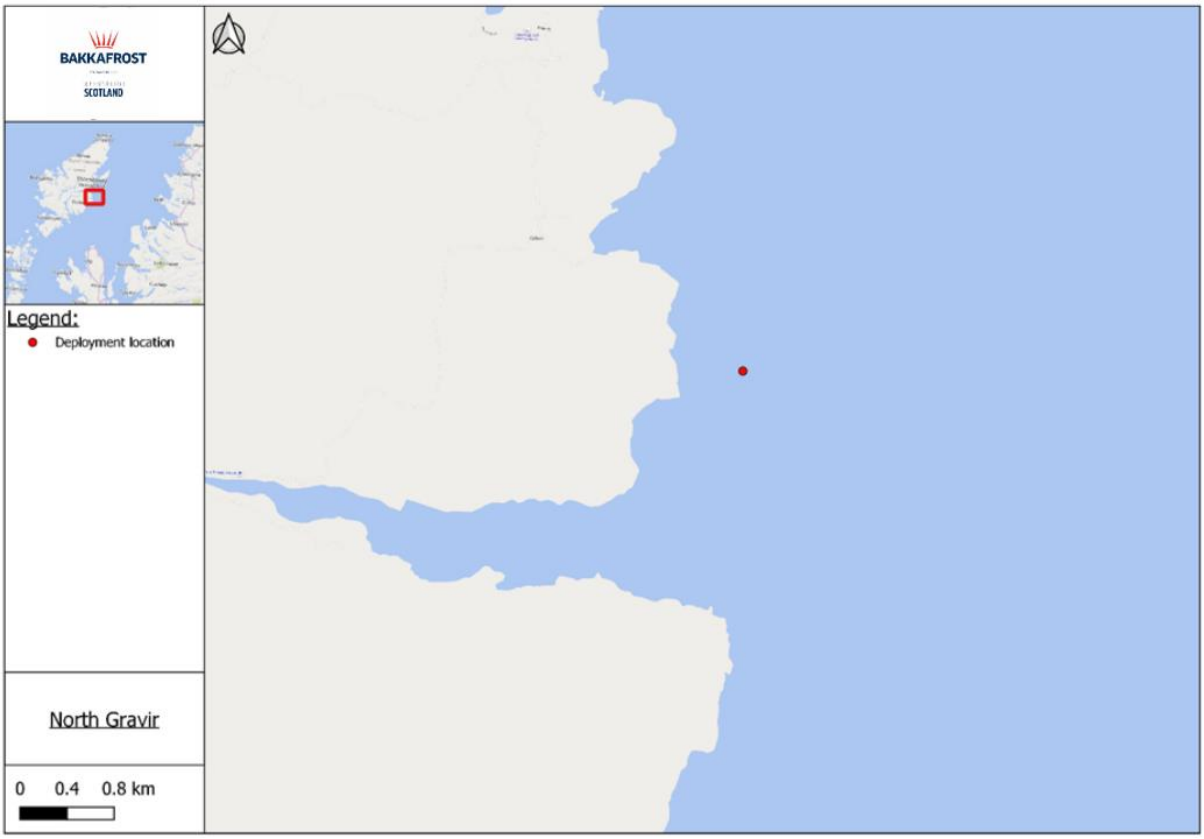

Figure 0.1. Location of the North Gravir meter deployment (red dot).

Materials and Methods

1.1 Bathymetry Survey

BFS have not conducted a bathymetry survey at this location because high resolution Admiralty data was already available. This was collected and stored as part of the "Maritime and Coastguard Agency (MCA) Bathymetric Survey HI1352, North Minch, (30/10/2011 to 05/12/2011)" bathymetry dataset (licenced under the Open Government Licence v3.0)[1] (Figure 0.1).

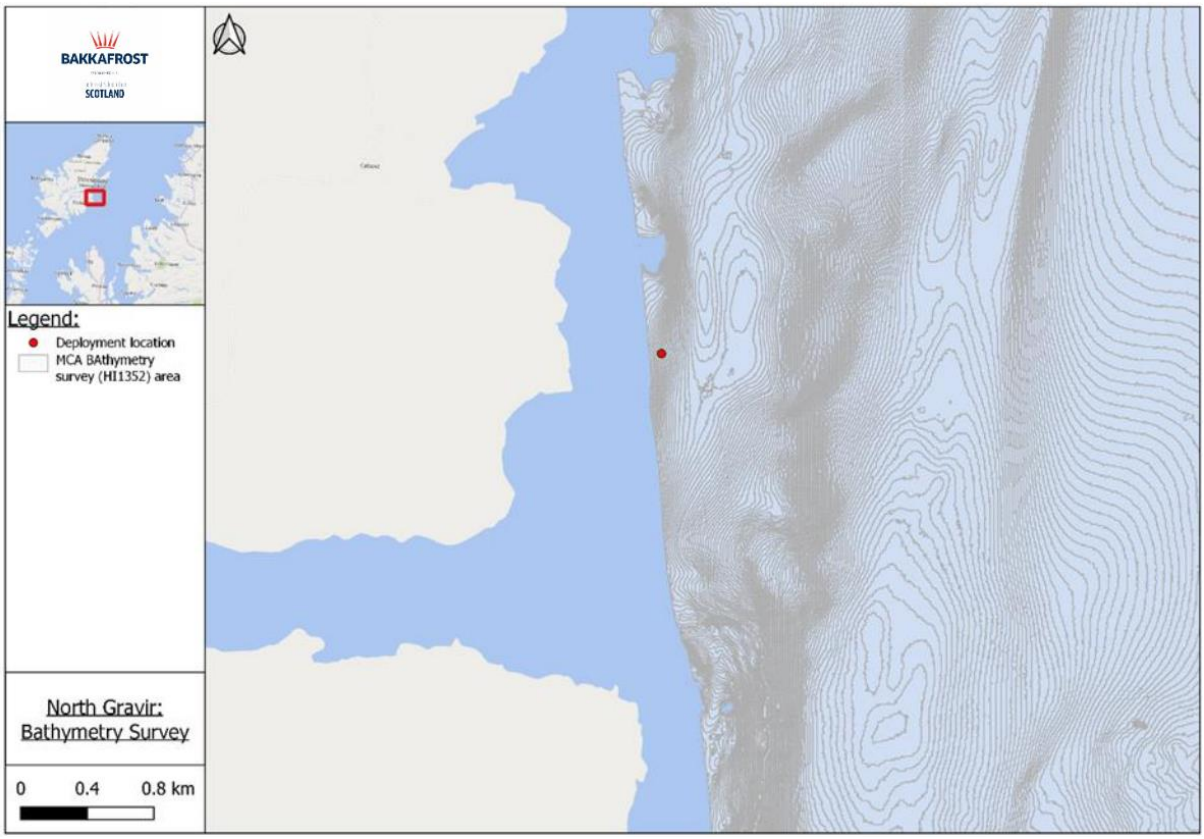

Figure 0.1. MCA Bathymetric Survey (HI1352) area surrounding North Gravir (30/10/2011 to 05/12/2011).

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 proposed fish farm location.

1.2 Current Meter Set-up

An ADCP was used to record current data at the North Gravir site during two seperate deployments. The ADCP was installed in a mooring frame with 20° free gimbal movement that automatically levels the instrument when deployed on the seabed. The Workhorse ADCP is a 500kHz 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 80 m depths. Further information on the ADCP can be found at:

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

[1] Admiralty Maritime Data Solutions (2021). Seabed Mapping Service. [online] Available at: <https://seabed.admiralty.co.uk/> [Accessed 12 August 2021].

The ADCP was deployed twice during 2021, in order to collect at least 90 days of current meter data[2]. The details of these deployments are shown in Table 0.1. Further details are available in Appendix 1. The transducer head was 60 cm from the base of the mooring frame.

Table 0.1 North Gravir deployment details

	Deployment	Start date/time	End date/time	Location (OSGB36)	Location (WGS 84)
North Gravir 1	1	04/08/2021 15:09	06/10/2021 08:09	143051 E, 916012 N	58°3.509'N, 06°21.452'W
North Gravir 2	2	08/10/2021 15:00	10/12/2021 22:00	143021 E, 915986 N	58°3.494'N, 6°21.480'W

Initial depth soundings were taken at the deployment site, in order to determine the depth the ADCP would be situated in during high tide and in order for the appropriate column range to be determined. The ADCP was configured at the time of deployment, having established the water depth and expected tidal range on site. This was carried out on the instrument settings using a laptop with wireless connectivity.

1.3 Magnetic Variation

No magnetic variation correction was made to the ADCP during the deployment, this was undertaken after the instrument was recovered and data downloaded. A convergence value of -3.70° was applied. The grid magnetic angle applied was 0.65° for the first deployment and 0.69° for the second deployment. This gave an overall declination of -3.05° and -3.01°, respectively.

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

1.4 Data Processing

Data was downloaded and viewed using 'Velocity', a bespoke software for use with Teledyne instruments. Initial 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 the software, the data was extracted to text files and then later further processed in MATLAB and Microsoft Excel.

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

For both deployments, the near-bottom cell chosen was cell 1, giving a height above the seabed of 2.58 m, with depths ranging from 52.33 m to 57.70 m. Each cage-bottom and sub-surface cell for each deployment was calculated based on recorded depths. The calculated cell number and their depths are shown in Table 0.2.

[2] These datasets, including the final 90+-day stitched dataset, have been sent to SEPA under reference Site G. SEPA confirm, in email correspondence on 01/03/2022, that the data is of good quality and can be used in an application.

Table 0.2 Summary of the cell number and their depths for each dataset.

Deployment		Near-bottom Cell	Cage-bottom Cell	Sub-surface Cell
North Gravir 1	**Cell Number**	1	41	49
	Distance from seabed (m)	2.58	42.58	50.58
	Distance from surface (m)	52.86	10.88	2.88
North Gravir 2	**Cell Number**	1	41	45
	Distance from seabed (m)	2.58	42.58	46.58
	Distance from surface (m)	52.33	10.35	6.35

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, which equated to 1.98 m for both deployments. 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, 2.58 m, which is within the remit of the SEPA criteria of 3 m.

Standard deviation has been assessed throughout the deployment to identify accurate and reliable data for near-bed, cage-bottom and sub-surface cells. The instrument standard deviation is determined using the deployment settings when the meter is programmed. Standard deviation for both deployments were within the SEPA criteria of 0.02 cm/s.

Results and Discussion

1.5 Bathymetry Survey

Bathymetry data was gathered between 30/10/2011 to 05/12/2011 by the MCA, using an Echosounder - multibeam survey. This data was used to validate Admiralty chart data for the area. The surveys concluded that chart data was reliable throughout the survey area. A combination of the collected depth data and Admiralty chart data was used to represent the bathymetry around the proposed North Gravir site (Figure 0.1). The mean wetted depth for the 2 x 2 km area was 60.92 mCD.

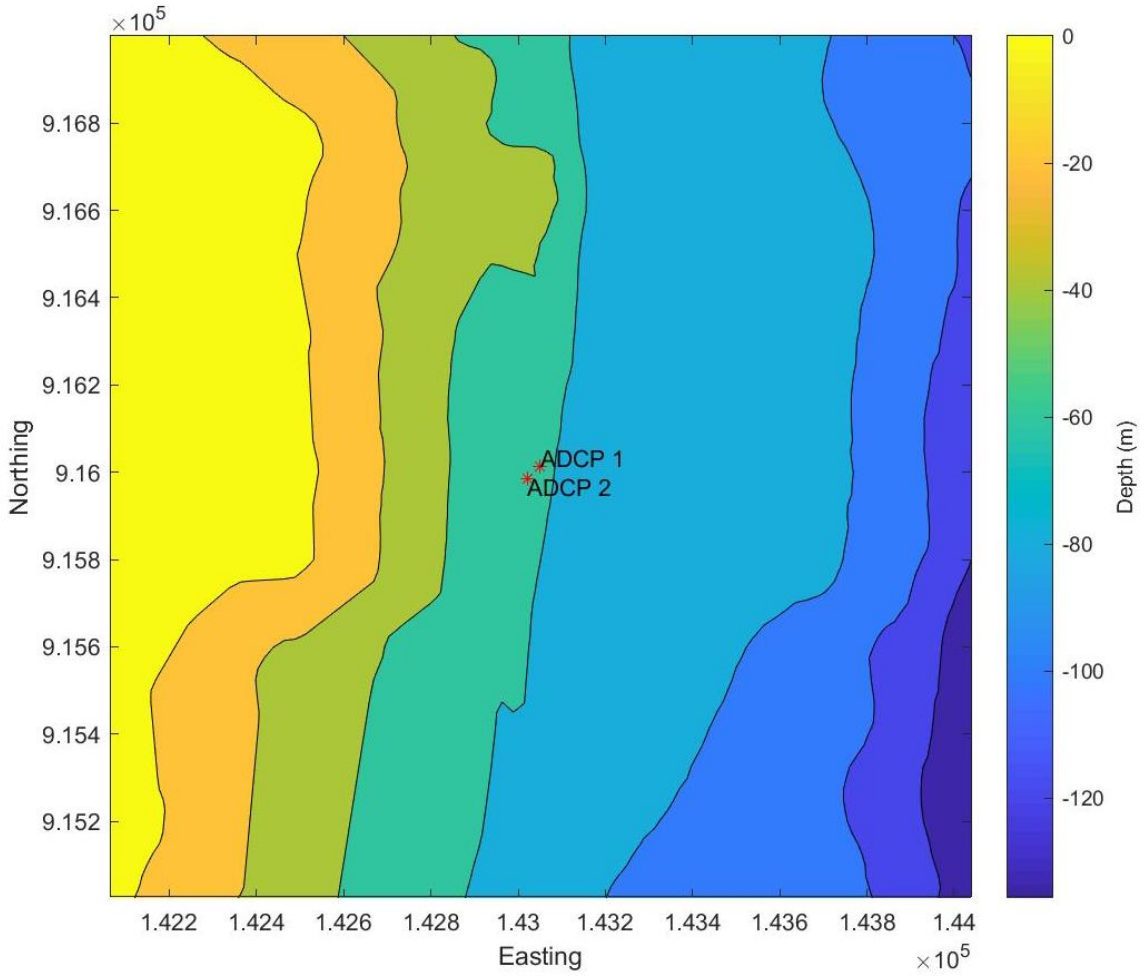

Figure 0.1. Representation of bathymetry in a 2 x 2 km grid around the proposed North Gravir site. The two current meter locations are shown (ADCP).

1.6 Current Data

During the initial processing stages, pitch, roll and heading were analysed to ensure the deployments were successful. This is presented in

Table 0.1, Figure 0.2 and Figure 0.3. These values are within the accepted range for successful deployments.

Table 0.1. Pitch, roll and heading range for the two North Gravir deployments.

Deployment	Pitch (°)	Roll (°)	Heading (°)
North Gravir 1	0.55	0.77	4.94
North Gravir 2	2.66	3.67	16.32

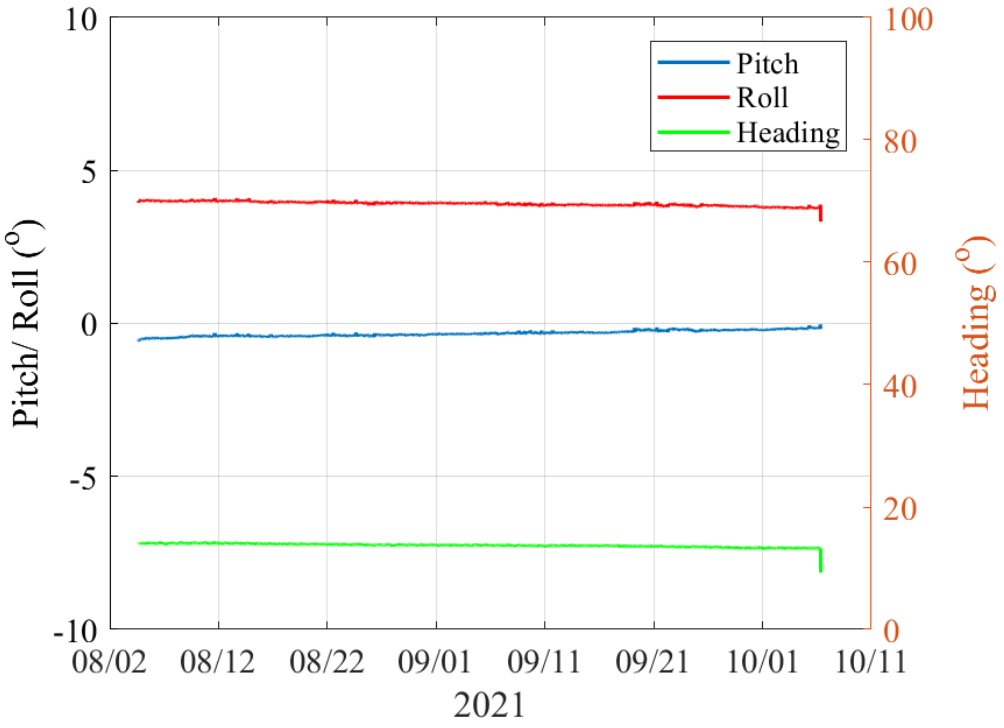

Figure 0.2. Pitch, roll and heading for North Gravir deployment 1, from 04/08/2021 - 06/10/2021.

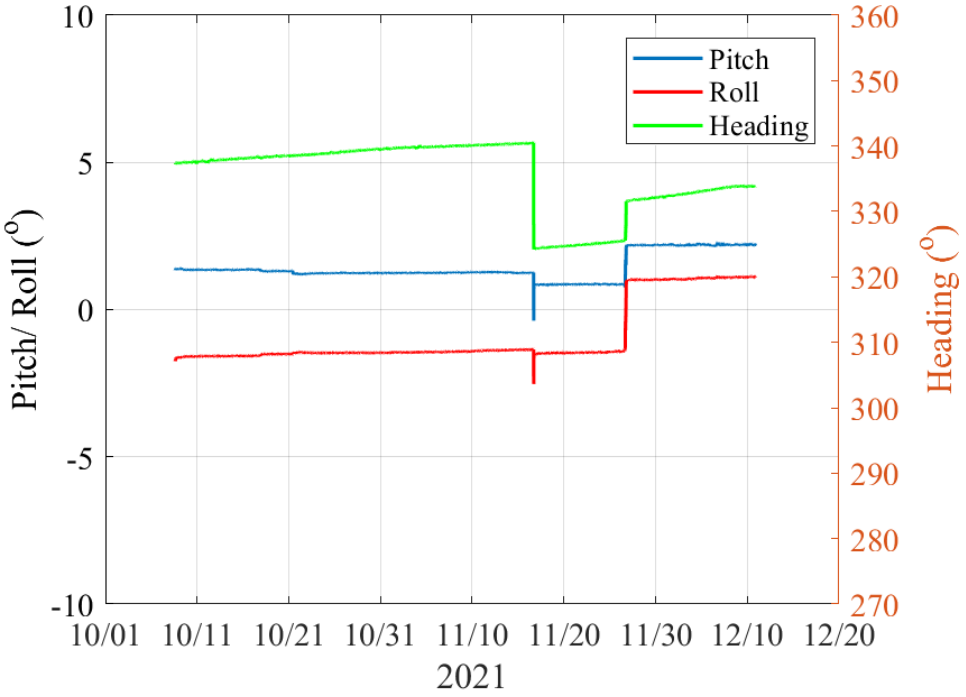

Figure 0.3. Pitch, roll and heading for North Gravir deployment 2, from 08/10/2021 - 10/12/2021.

A summary of the current data is shown in Appendix 1, and the SEPA HG analysis summary details are provided in Appendix 2.

A summary of the current data is shown in Table 0.2 and Table 0.3. During the first deployment, the sub-surface, cage-bottom and near-bed cells had averages of 15.6 cm/s, 15.2 cm/s and 12.9 cm/s respectively. This gave an overall average of 14.6 cm/s. During the second (final) deployment, the sub-surface, cage-bottom and near-bed cells had averages of 16.7 cm/s, 16.4 cm/s and 13.2 cm/s respectively. This gave an overall average of 15.4 cm/s. The orientation axis of the velocities was 180° to 360° at all the selected cells. These orientations are all consistent with a parallel flow to the shoreline. Further details on hydrographic meter deployment results are provided in Appendix 1.

The mean residual currents for the sub-surface, cage-bottom and near-bed cells are 6.0 cm/s, 5.7 cm/s and 3.0 cm/s for the first deployment, with an overall average of 4.9 cm/s; and 2.0 cm/s, 2.5 cm/s and 1.3 cm/s for the second deployment, with an overall average of 1.9 cm/s. The direction of the residual current at the subsurface and cage-bottom cell was along the NNW-SSE axis, whereas at near-bed cell it was along a southward orientation. The residual currents recorded during the deployment indicate that there is wind influence, but tidal flow is the dominant flow.

Table 0.2. Summary of currents recorded at North Gravir deployment 1.

	Mean Speed (cm/s)	Residual Speed (cm/s)	Residual direction °T	Major axis °T
Sub-surface	15.6	6.0	176	180
Cage-bottom	15.2	5.7	177	175
Near-bed	12.9	3.0	147	170

Table 0.3. Summary of currents recorded at North Gravir deployment 2.

	Mean Speed (cm/s)	Residual Speed (cm/s)	Residual direction °T	Major axis °T
Sub-surface	16.7	2.0	332	360
Cage-bottom	16.4	2.5	325	360
Near-bed	13.2	1.3	137	175

The data collected was near-consecutive, meaning data 'stitching' was straightforward. Data was 'stitched' together to form a 128-day dataset in such a way as to minimise error between Spring-Neap cycles (Water level for near-bed cell shown in Figure 0.4). Table 0.4 shows the two datasets and their Spring-Neap cycles, 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 0.4. North Gravir current meter tidal cycles.

Dataset	Deployment	Start	Tide	Spring Time (days)	End	Tide	Spring Time (days)
North Gravir 1	1	04/08/2021 15:09	1.5 hrs before high	6 before	06/10/2021 08	5 hrs after high	2 before
Fill gap	2	04/12/2021 07:40	1.5 hrs after high	2 before	06/12/2021 15:20	1 hr after low	Spring
North Gravir 2	2	08/10/2021 15:00	1 hr after low	Spring	10/12/2021 22	4 hrs after low	4 after

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 water depth for the stitched dataset was calculated using the weighted average deployment depths (55.3 m). The cell distances above the bed are also weighted by the deployment lengths, as per SEPA's latest guidance[3] (Table 0.5). Distances below the surface are then calculated using the weighted average deployment depth minus the weighted average height above bed of each cell.

Table 0.5 Average height and weighted average height above the bed.

[3] SEPA (2022*), HG Data for Aquaculture Applications– Feb 2022*

Average height above bed	North Gravir deployment 1	North Gravir deployment 2	Weighted average for stitched dataset
Sub-surface	50.58	46.58	48.57
Cage-bottom	42.58	42.58	42.58
Near-bed	2.58	2.58	2.58

The SEPA HG analysis spreadsheet for the 128 days of current data is shown in Appendix 2. For the 128-day dataset the sub-surface, cage-bottom and near-bed cells had averages of 16.2 cm/s, 15.9 cm/s and 13.1 cm/s respectively. This gave an overall average of 15.1 cm/s. The orientation of the velocities was south at all selected 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 are 2.1 cm/s, 1.9 cm/s and 2.1 cm/s, with an overall average of 2.0 cm/s. The direction of the residual current was south-southwest at the sub-surface and cage-bottom cells and southeast at the near-bed cell.

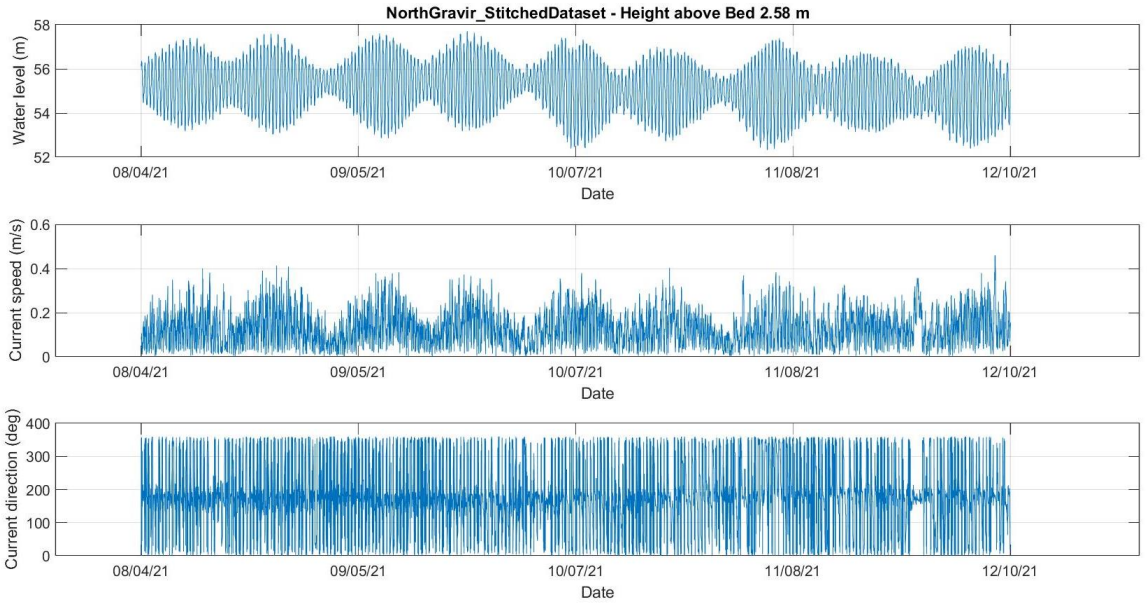

Figure 0.4 Timeseries of water level, current speed and direction at the near-bed cell for the 128-day stitched dataset.

The SEPA HG analysis spreadsheet in Appendix 2 shows that the currents are above the critical resuspension threshold of 0.095 m/s, at the near-bed cell, 63% of the time. However, the recent SEPA guidance (detailed in Section 0) documents a threshold of 0.085 m/s for the critical resuspension at the near-bed cell. The flow is above this critical threshold for 67% of the dataset. The timeseries of near-bed current speed shows that there are sustained periods of elevated flow and a maximum speed of 0.46 m/s (Figure 0.4).

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 hydrographic data. This longer deployment schedule has been achieved through multiple deployments, an extended time period and likely represents 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 hydrographic 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.

Conclusion

Bathymetry and hydrographic data have been collected at the proposed North Gravir site. The results from two deployments, totalling 128 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 stitched 128-day dataset is predominantly tidally driven and indicative of a well flushed site. Therefore, this dataset is considered suitable for further use in modelling and are considered to provide a good basis for hydrodynamic and bath treatment modelling.

Meteorological data was not collected.

Appendices

1.7 Appendix 1: Summary of current meter data for the North Gravir deployments

Table 0.1. Summary of currents recorded at North Gravir deployment 1.

No. of records	4516		
Start date / time	04/08/2021 15:09:00		
End date / time	06/10/2021 08:09:00		
Initial deployment depth (mCD)	55.0		
	Near-bed	**Cage-bottom**	**Sub-surface**
Cell Number	1	41	49
Mean speed (m/s)	0.129	0.152	0.156
Residual speed (m/s)	0.030	0.057	0.060
Residual direction °T	147	177	176
Major axis °T	170	175	180
Residual parallel (m/s)	0.027	0.057	0.060
Residual normal (m/s)	-0.012	0.002	-0.004
Amplitude parallel (m/s)	0.195	0.236	0.239
Amplitude normal (m/s)	0.071	0.066	0.069
Resuspension Threshold (9.5cm/s)	62%	65%	66%

Table 0.2. Summary of currents recorded at North Gravir deployment 2.

No. of records	4558		
Start date / time	08/10/2021 15:00:00		
End date / time	10/12/2021 22:00:00		
Initial deployment depth (mCD)	55.6		
	Near-bed	**Cage-bottom**	**Sub-surface**
Cell Number	1	41	45
Mean speed (m/s)	0.132	0.164	0.167
Residual speed (m/s)	0.013	0.025	0.020
Residual direction °T	137	325	332
Major axis °T	175	360	360
Residual parallel (m/s)	0.010	0.020	0.017
Residual normal (m/s)	-0.008	-0.014	-0.009
Amplitude parallel (m/s)	0.203	0.266	0.271
Amplitude normal (m/s)	0.073	0.057	0.060
Resuspension Threshold (9.5cm/s)	63%	68%	69%

1.8 Appendix 2: HG analysis spreadsheets for the North Gravir deployments.

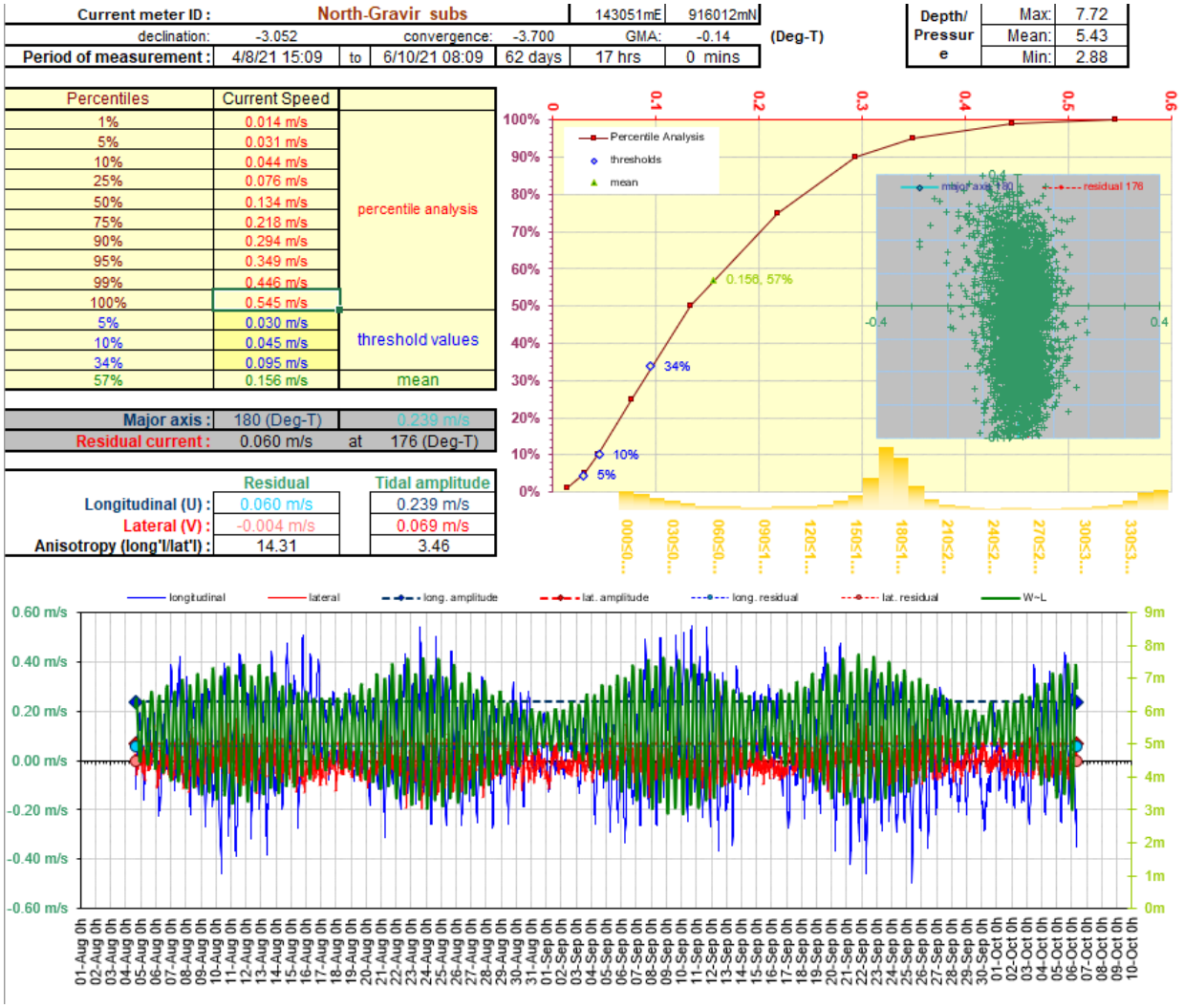

Figure.1. HG analysis summary of the sub-surface cell for North Gravir 1st deployment.

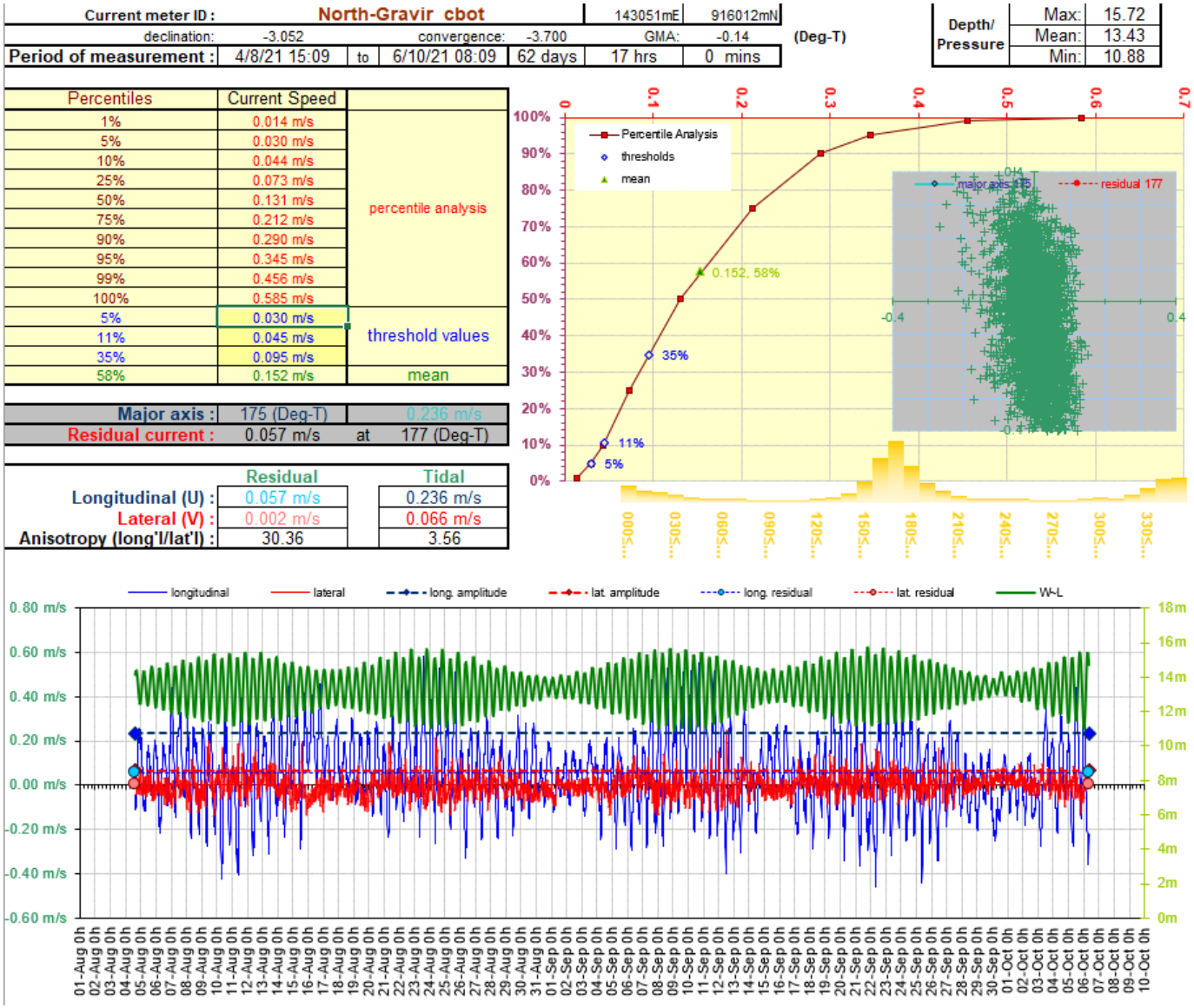

Figure 0.2. HG analysis summary of the cage-bottom cell for North Gravir 1st deployment.

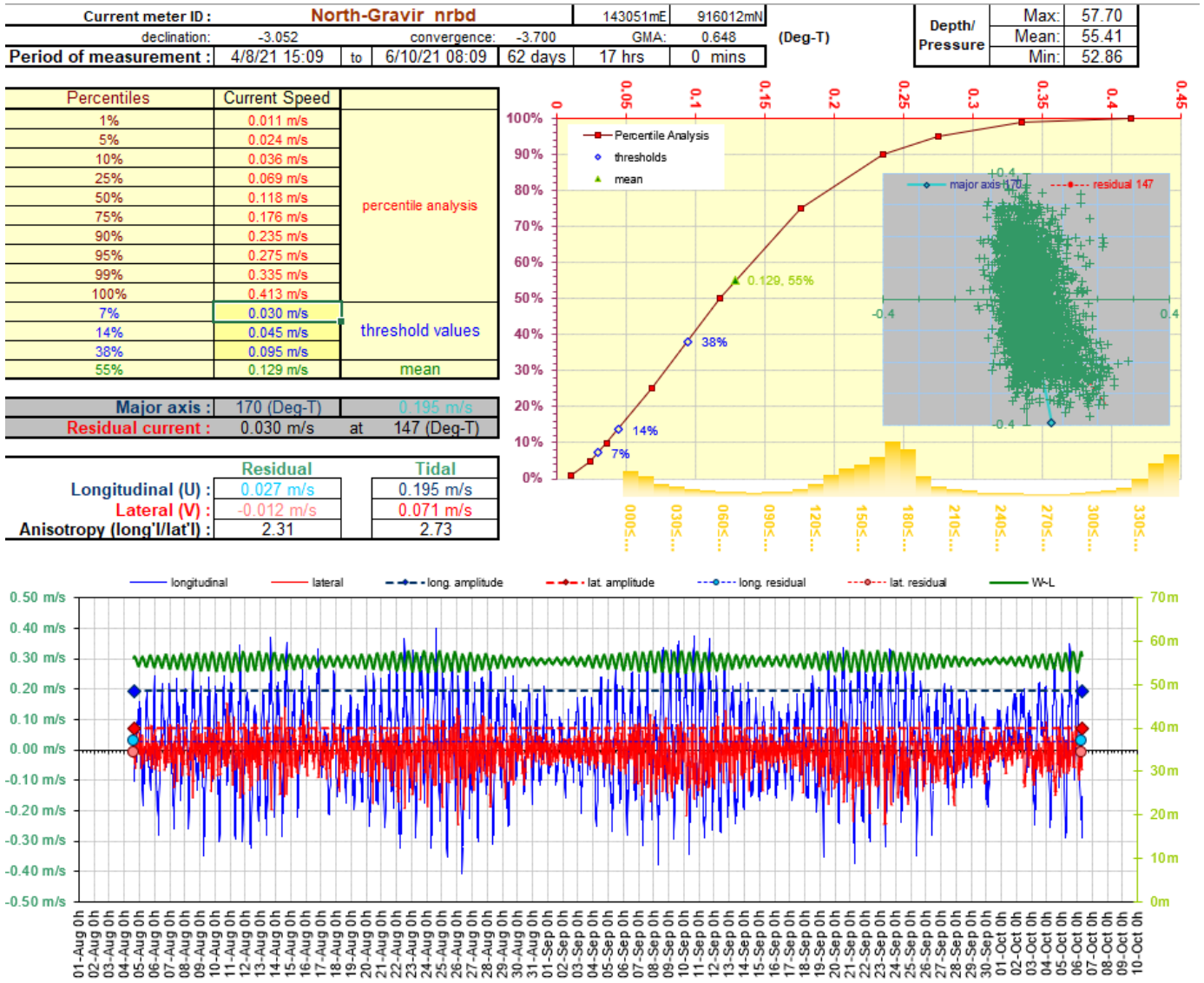

Figure 0.3. HG analysis summary of the near-bed cell for North Gravir 1st deployment.

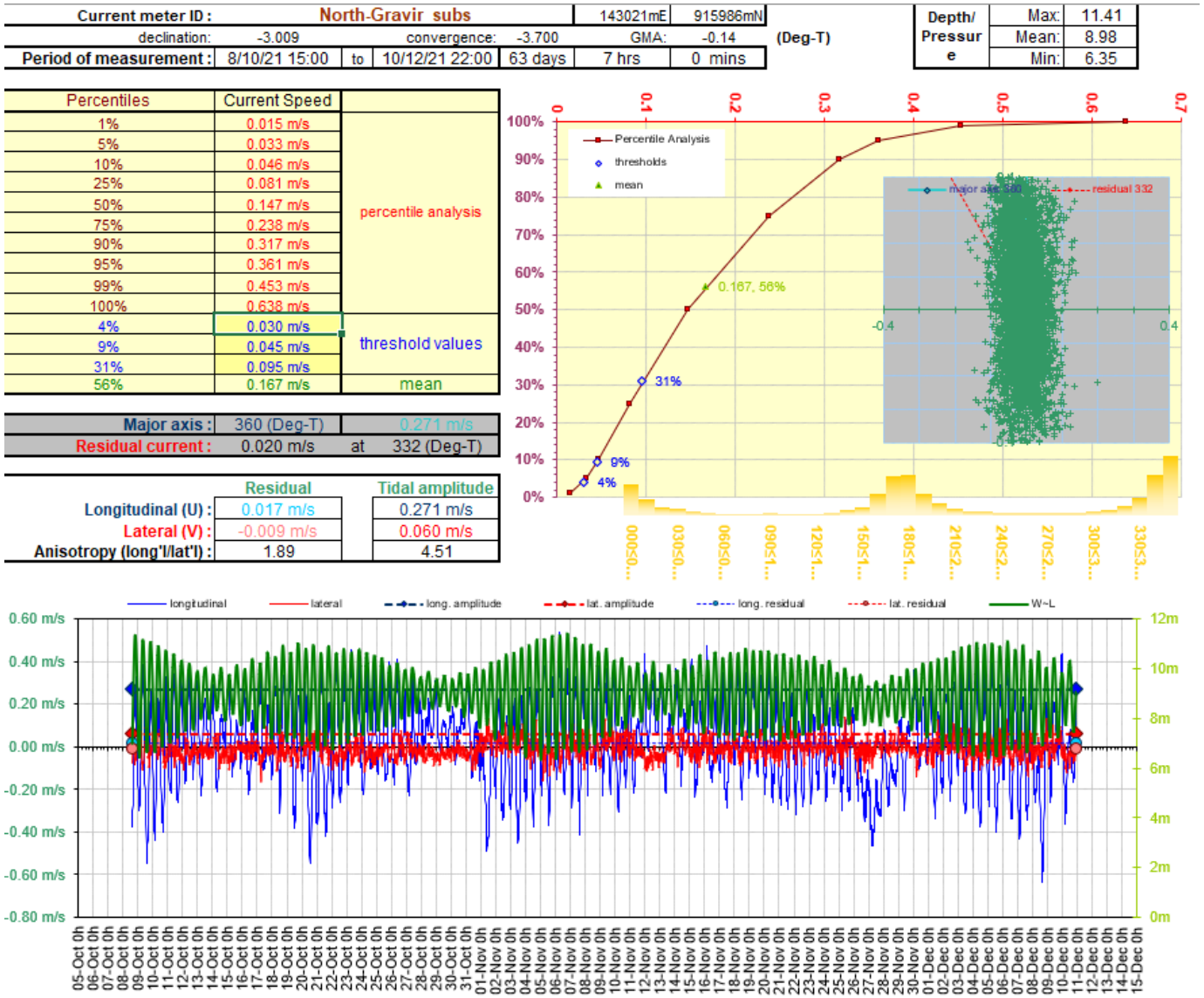

Figure 0.4. HG analysis summary of the sub-surface cell for North Gravir 2nd deployment.

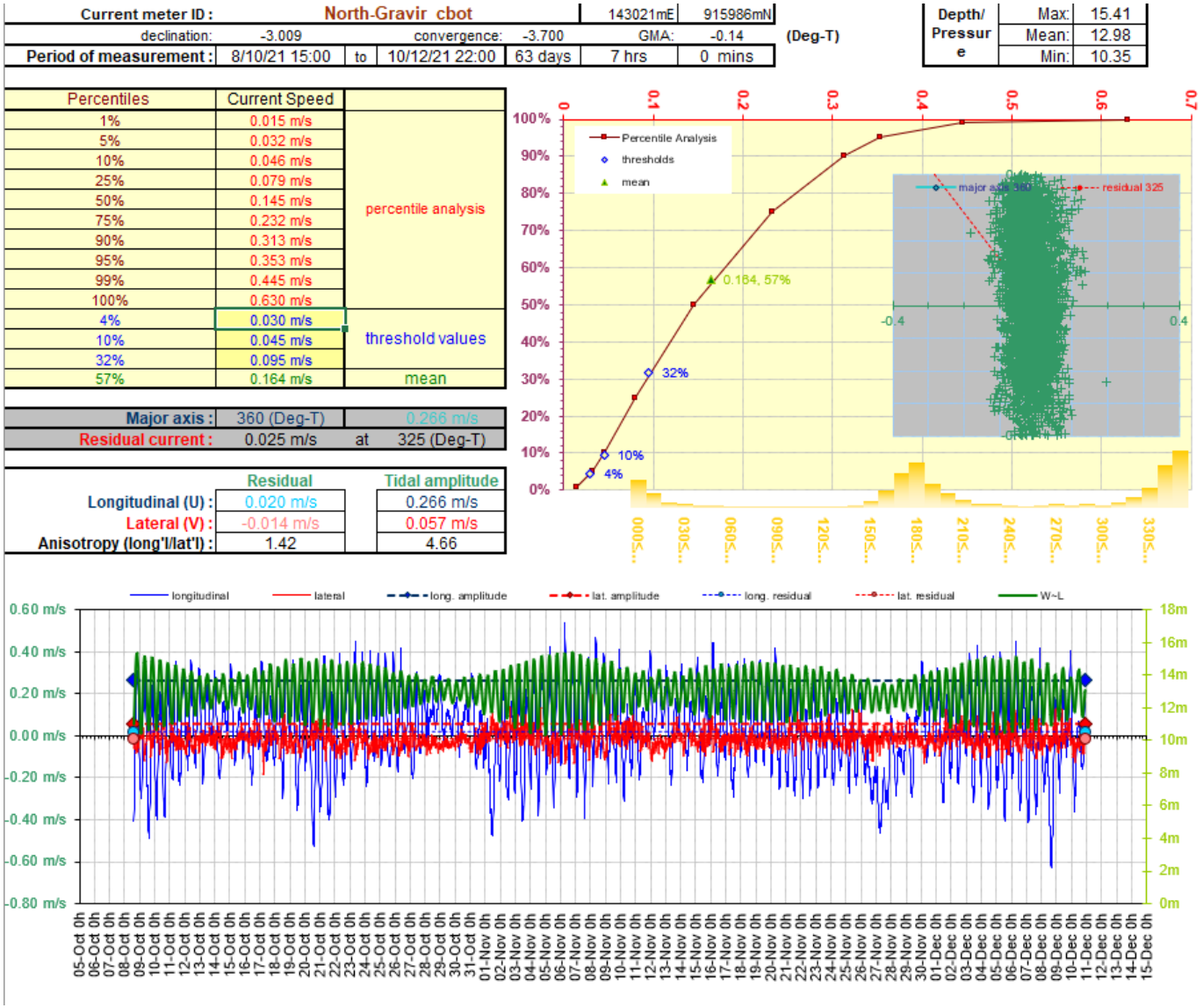

Figure 0.5. HG analysis summary of the cage-bottom cell for North Gravir 2nd deployment.

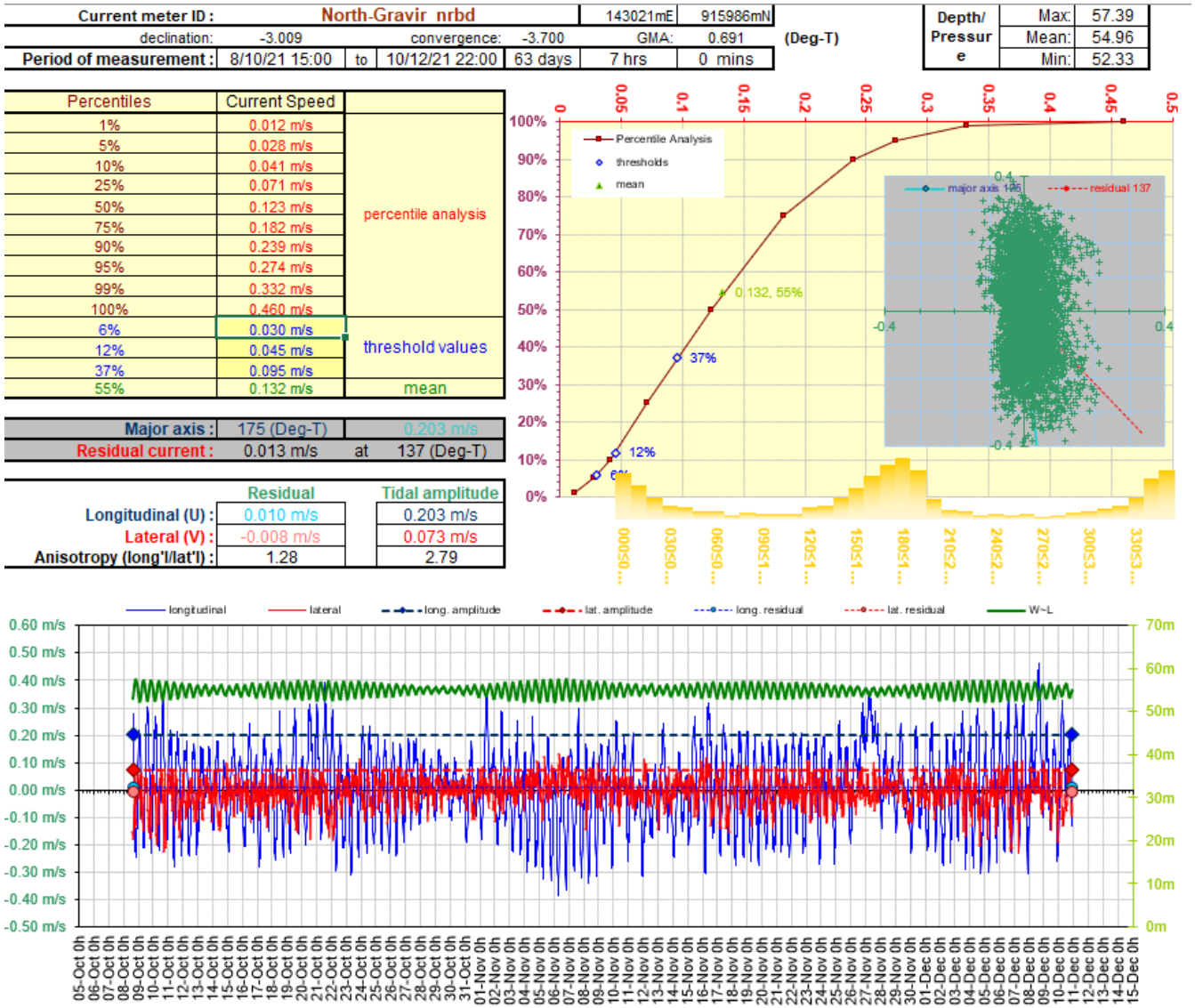

Figure 0.6. HG analysis summary of the near-bed cell for North Gravir 2nd deployment.

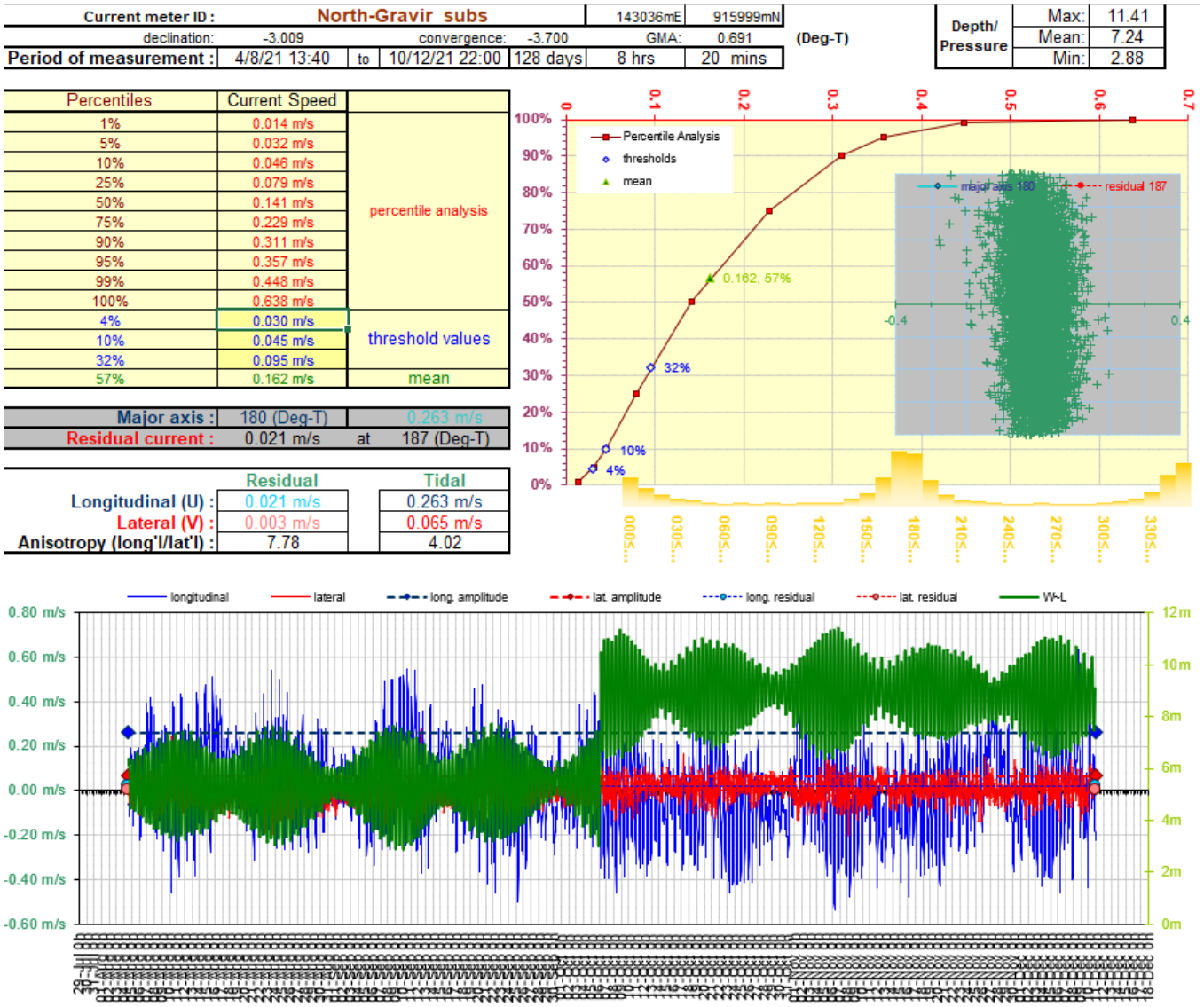

Figure 0.7. HG analysis summary of the sub-surface cell for North Gravir 128 days.

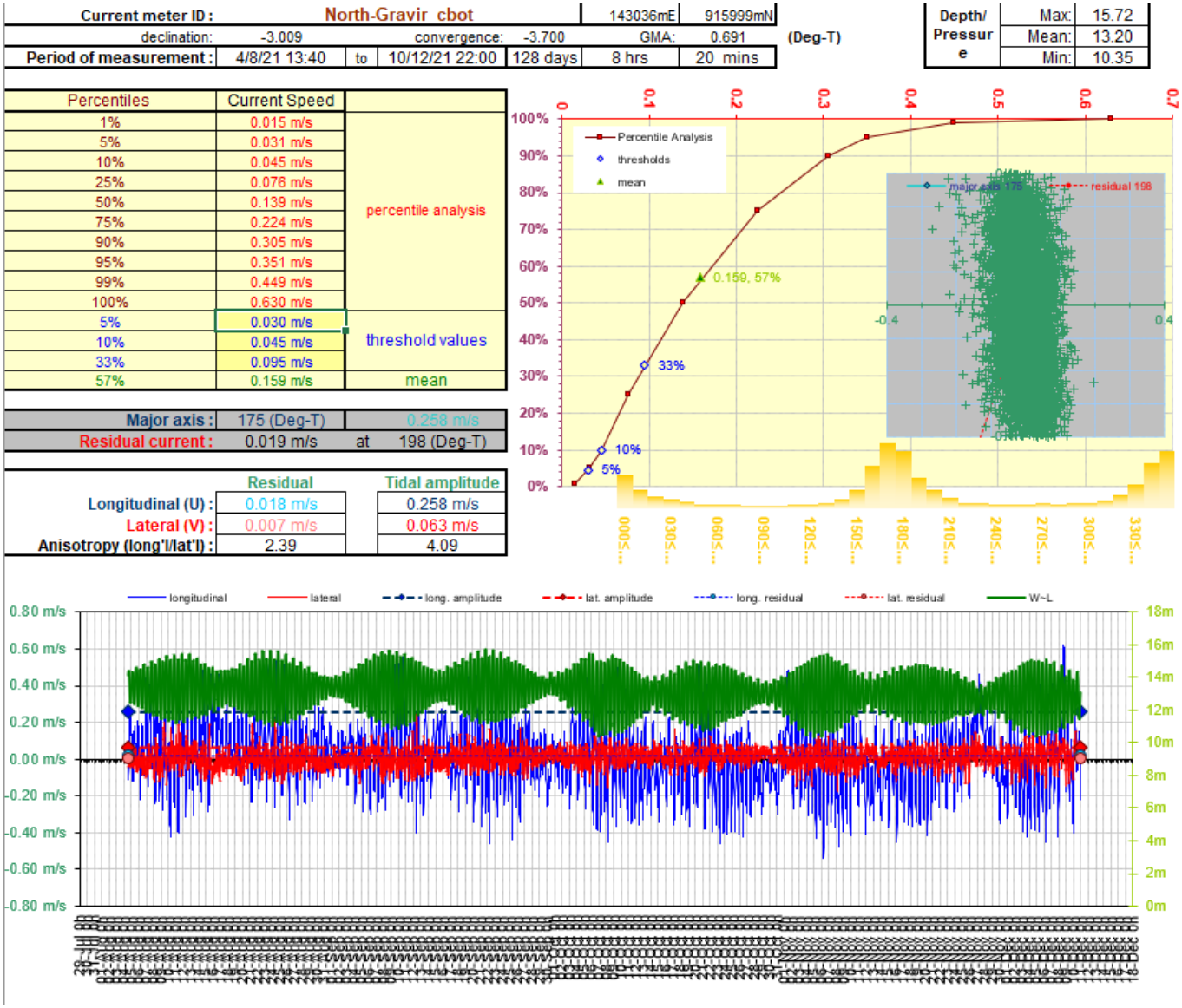

Figure 0.8. HG analysis summary of the cage-bottom cell for North Gravir 128 days.

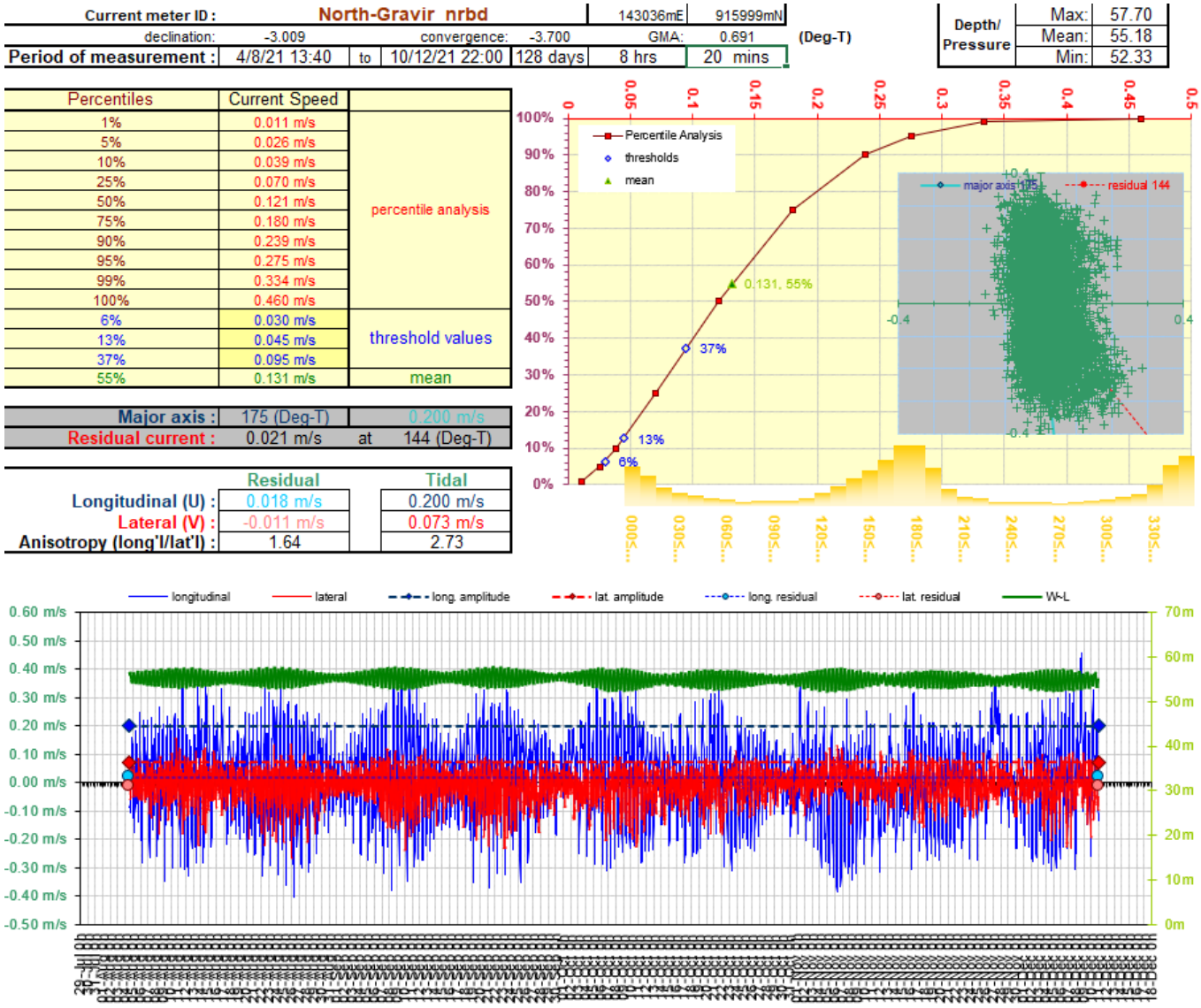

Figure 0.9. HG analysis summary of the near-bed cell for North Gravir 128 days.