Sheringham Shoal and Dudgeon Offshore Wind Farm Extension Projects

Marine Processes Technical Note (Revision B) (Clean)

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Prepared by:		
Royal HaskoningDHV		
Approved by:		Date:
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Glossary of Acronyms

CSCB	Cromer Shoal Chalk Beds
DEL	Dudgeon Extension Limited
DEP	Dudgeon Offshore Wind Farm Extension Project
DOW	Dudgeon Offshore Wind Farm
ECC	Export Cable Corridor
ES	Environmental Statement
ES	Environmental Statement
HDD	Horizontal Directional Drilling
LAT	Lowest Astronomical Tide
MCZ	Marine Conservation Zone
MPA	Marine Protected Area
NW	Northwest
OWF	Offshore Wind Farm
OWF	Offshore Wind Farm
PEIR	Preliminary Environmental Information Report
RIAA	Report to Inform Appropriate Assessment
SEL	Scira Extension Limited
SEP	Sheringham Offshore Wind Farm Extension Project
SOW	Sheringham Shoal Offshore Wind Farm
SSC	Suspended Sediment Concentration

Glossary of Terms

Dudgeon Offshore Wind Farm Extension Project (DEP)	The Dudgeon Offshore Wind Farm Extension onshore and offshore sites including all onshore and offshore infrastructure.
DEP offshore site	The Dudgeon Offshore Wind Farm Extension consisting of the DEP wind farm site, interlink cable corridors and offshore export cable corridor (up to mean high water springs).
DEP North array area	The wind farm site area of the DEP offshore site located to the north of the existing Dudgeon Offshore Wind Farm
DEP South array area	The wind farm site area of the DEP offshore site located to the south of the existing Dudgeon Offshore Wind Farm
DEP wind farm site	The offshore area of DEP within which wind turbines, infield cables and offshore substation platform/s will be located and the adjacent Offshore Temporary Works Area. This is also the collective term for the DEP North and South array areas.
Horizontal directional drilling (HDD) zones	The areas within the onshore cable route which would house HDD entry or exit points.
Infield cables	Cables which link the wind turbine generators to the offshore substation platform(s).
Interlink cables	Cables linking two separate project areas. This can be cables linking: 1) DEP South array area and DEP North array area 2) DEP South array area and SEP 3) DEP North array area and SEP 1 is relevant if DEP is constructed in isolation or first in a phased development. 2 and 3 are relevant where both SEP and DEP are built.
Interlink cable corridor	This is the area which will contain the interlink cables between offshore substation platform/s and the adjacent Offshore Temporary Works Area.
Landfall	The point at the coastline at which the offshore export cables are brought onshore, connecting to the onshore cables at the transition joint bay above mean high water

Offshore cable corridors	This is the area which will contain the offshore export cables or interlink cables, including the adjacent Offshore Temporary Works Area.
Offshore export cable corridor	This is the area which will contain the offshore export cables between offshore substation platform/s and landfall, including the adjacent Offshore Temporary Works Area.
Offshore export cables	The cables which would bring electricity from the offshore substation platform(s) to the landfall. 220 – 230kV.
Sheringham Shoal Offshore Wind Farm Extension Project (SEP)	The Sheringham Shoal Offshore Wind Farm Extension onshore and offshore sites including all onshore and offshore infrastructure.
SEP offshore site	Sheringham Shoal Offshore Wind Farm Extension consisting of the SEP wind farm site and offshore export cable corridor (up to mean high water springs).
SEP wind farm site	The offshore area of SEP within which wind turbines, infield cables and offshore substation platform/s will be located and the adjacent Offshore Temporary Works Area.
The Applicant	Equinor New Energy Limited. As the owners of SEP and DEP, Scira Extension Limited and Dudgeon Extension Limited are the named undertakers that have the benefit of the DCO. References in this document to obligations on, or commitments by, ‘the Applicant’ are given on behalf of SEL and DEL as the undertakers of SEP and DEP.

1 Revision B Updates at Deadline 3

1. This document has been updated at Deadline 3 to address comments from Natural England received at Deadline 2 [REP2-062] (see **Section 2.5.2**).

2 Response to Natural England Comments

2. The comments received within Appendix E of Natural England's Relevant Representations [RR-063] which the Applicant considers are required to be addressed within this Technical Note are grouped into the following five categories:

- Baseline Characterisation of Bedforms (**Section 2.1**);
- Baseline Tidal Ellipses (**Section 2.2**);
- Marine Protected Areas (MPA) and the Zone of Potential Tidal Influence (**Section 2.3**);
- Potential Impacts on Suspended Sediment Concentrations (**Section 2.4**); and
- Local Changes to the Seabed Bathymetry at Dudgeon Offshore Wind Farm (DOW) Post Construction (**Section 2.5**).

3. See **The Applicant's Comments on Relevant Representations** [document reference 12.3] for the Applicant's point-by-point response to Appendix E of Natural England's Relevant Representation [RR-063]. Note that where references to comments at 'ID X' are provided, these are in relation to the rows within the Applicant's comments on Appendix E Marine Processes of Natural England's Relevant Representation [RR-063] located in the **Applicant's Comments on Relevant Representations** [document reference 12.3].

2.1 Baseline Characterisation of Bedforms

4. There are four related comments on the need for further detail on the baseline characterisation of bedforms and significant morphological features, particularly sandbanks and sandwaves. These are included below for ease of reference.

2.1.1 Natural England Comments at ID 3, ID 8, ID 21, and ID 28

5. *ID 3: The baseline characterisation is generally good, although characterisation of sandbanks, sandwaves and significant morphological features across the project area is inadequate. Please see our detailed comments and advice regarding baseline characterisation of sandbanks, sandwaves and seabed morphological features.*

6. *ID 8: Sandbanks: We advise that sandbanks, sandwaves and other significant morphological features have not been adequately characterised or assessed in the ES. Potential changes to these features through activities such sandwave levelling or operation of the [Offshore Wind Farm] OWF could indirectly influence the [Marine Conservation Zone] MCZ and/or East Anglia Coast. We advise that further consideration should be given to the characterisation of sandbanks, sandwaves and other significant morphological features, their migration rates, and recoverability over the lifetime of the project.*

7. *ID 21: The text describes a sandbank in [northwest] NW of DEP N array area and also a sandbank in the NW of DEP S array area. The bathymetry shows the presence of significant sandbanks, which are probably Cromer Knoll and Inner Cromer Knoll, but no information has been provided regarding their form, spatial extent, elevation, depth, rate of migration and stability. We would advise that in order to understand impacts of the development on these sandbank features, it is important to first characterise their form, extent, elevation, rate of migration and stability. Please can the Applicant provide this information in an updated chapter.*

8. *ID 28: Natural England notes that the 'Sand banks (and associated sandwaves)' Receptor Group does not include any mention of Sheringham Shoal, Pollard Bank, Cromer Knoll, Inner Cromer Knoll, sandwaves in SEP, sandbanks situated at the NW of DEP N array and in DEP S, and in the north of the cable corridor between DEP N array and SEP. We advise that all sandbanks within the OLs for the project, should be included and named, where possible in an updated chapter.*

2.1.2 Response

9. This response provides more detail (where available) on the form, spatial extent, elevation, depth and migration of:

- Cromer Knoll Bank and associated sandwaves in the northwest of the DEP North array area and at the northern ends of the interlink cable corridors between the DEP North array area and SEP, and the DEP North array area and the DEP South array area (Figure 6.1 and Figure 6.3 of the Environmental Statement (ES) [APP-119]);
- Inner Cromer Knoll Bank and associated sandwaves in the northwest of the DEP South array area (Figure 6.1 of the ES [APP-119]);
- Sheringham Shoal (Figure 6.4 of the ES [APP-119]); and
- Pollard Bank (Figure 6.4 of the ES [APP-119]).

2.1.2.1 Cromer Knoll Bank and Sandwaves

10. About 5km (running northwest to southeast) of the Cromer Knoll Bank crosses the northwest of the DEP North array area, with a further 3km at the northern end of the interlink cable corridor between the DEP North array area and SEP, and 3km at the northern end of the interlink cable corridor between the DEP North and South array areas (Figure 6.1 and Figure 6.3 of the ES [APP-119]). All three parts of the bank recorded in these areas are covered in sandwaves with crests oriented northeast to southwest (approximately). Gradients of greater than 10° are observed on the flanks of the sandwaves (Gardline, 2020).

11. The crest of the bank inside the northwest part of the DEP North array area and at the northern end of the interlink cable corridor between the DEP North array area and SEP has a shallowest depth of 13m below Lowest Astronomical Tide (LAT) and is up to 9m above the surrounding seabed (Gardline, 2020). Sandwaves up to 4-5m high with wavelengths of around 250m are prevalent across the bank. The bathymetry across these sandwaves is shown in Figure 1, a side-scan sonar example in **Figure 2** and a sub-bottom profiler example in **Figure 3**.

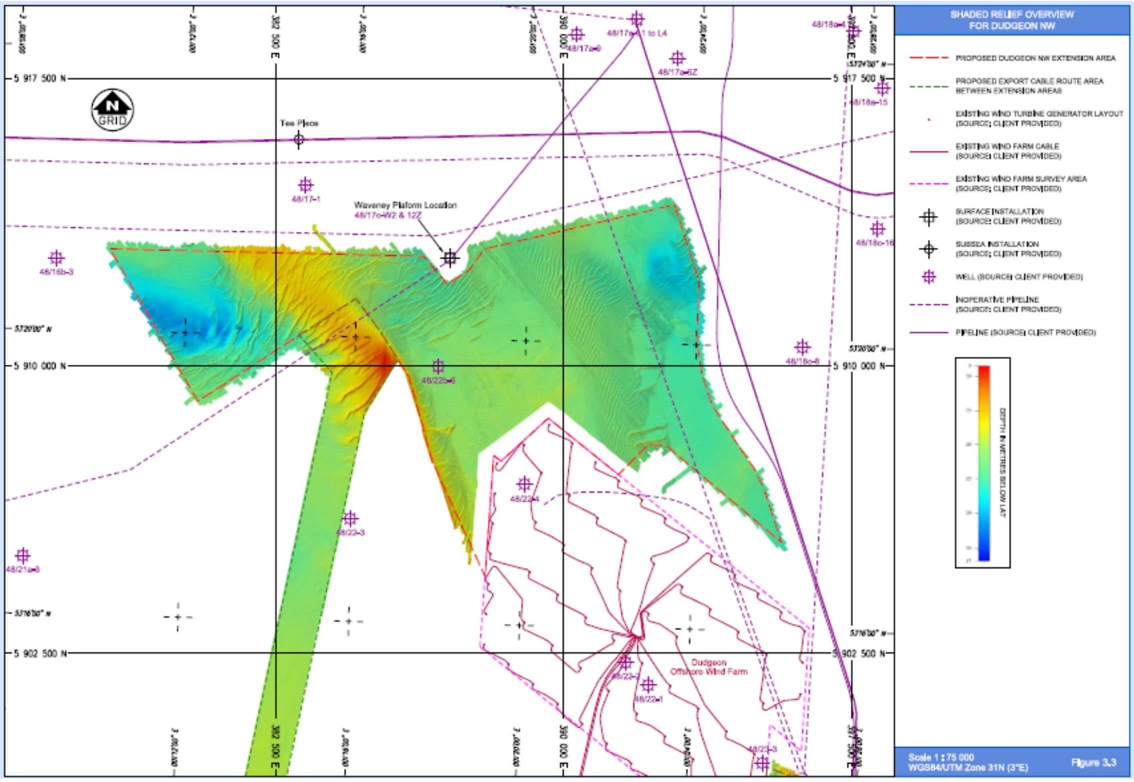

Figure 1 Bathymetry of the sandwaves across Cromer Knoll Bank at the northwest of the DEP North array area and at the northern end of the interlink cable corridor between the DEP North array area and SEP

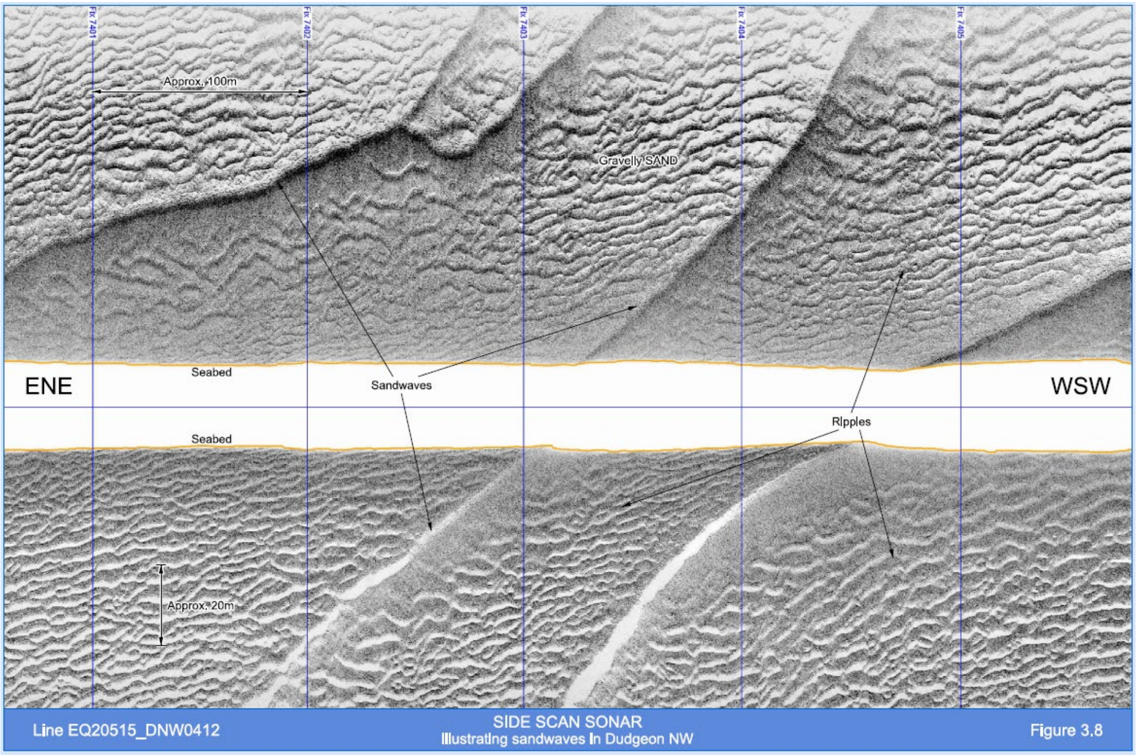

Figure 2 Side-scan sonar example of the sandwaves across Cromer Knoll Bank at the northwest of the DEP North array area and at the northern end of the interlink cable corridor between the DEP North array area and SEP

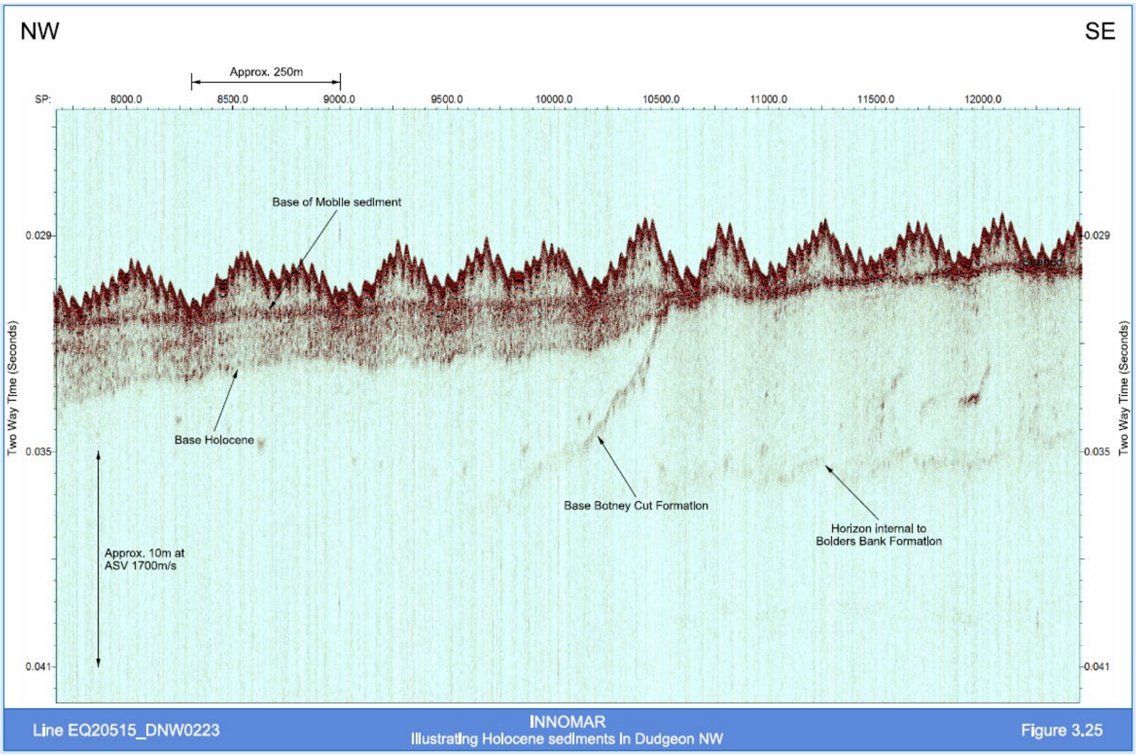

Figure 3 Sub-bottom profiler example of the sandwaves across Cromer Knoll Bank at the northwest of the DEP North array area and at the northern end of the interlink cable corridor between the DEP North array area and SEP

12. The bathymetry across the bank at the north end of the corridor between the DEP North and DEP South array areas is approximately 11-13m below LAT with superimposed sandwaves up to 3m high (DOW, 2009).

2.1.2.2 Inner Cromer Knoll Bank and sandwaves

13. The southeast 5km of Inner Cromer Knoll Bank (northwest to southeast oriented) is inside the northwest corner of the DEP South array area (Figure 6.1 of the ES [APP-119]). Here, the bank has a minimum depth of 11m below LAT and is about 4m above the surrounding seabed (Gardline, 2020).

14. This part of the bank is sculpted into a field of sandwaves with north-northeast to south-southwest crest orientations and heights of approximately 2-4m (with wavelengths of 250m), although they are more commonly 1-1.5m high (Gardline, 2020). Gradients of greater than 10° are observed on the flanks of the sandwaves (Gardline, 2020). The bathymetry across these sandwaves and a sub-bottom profiler example of them are shown in **Figure 4** and **Figure 5**, respectively.

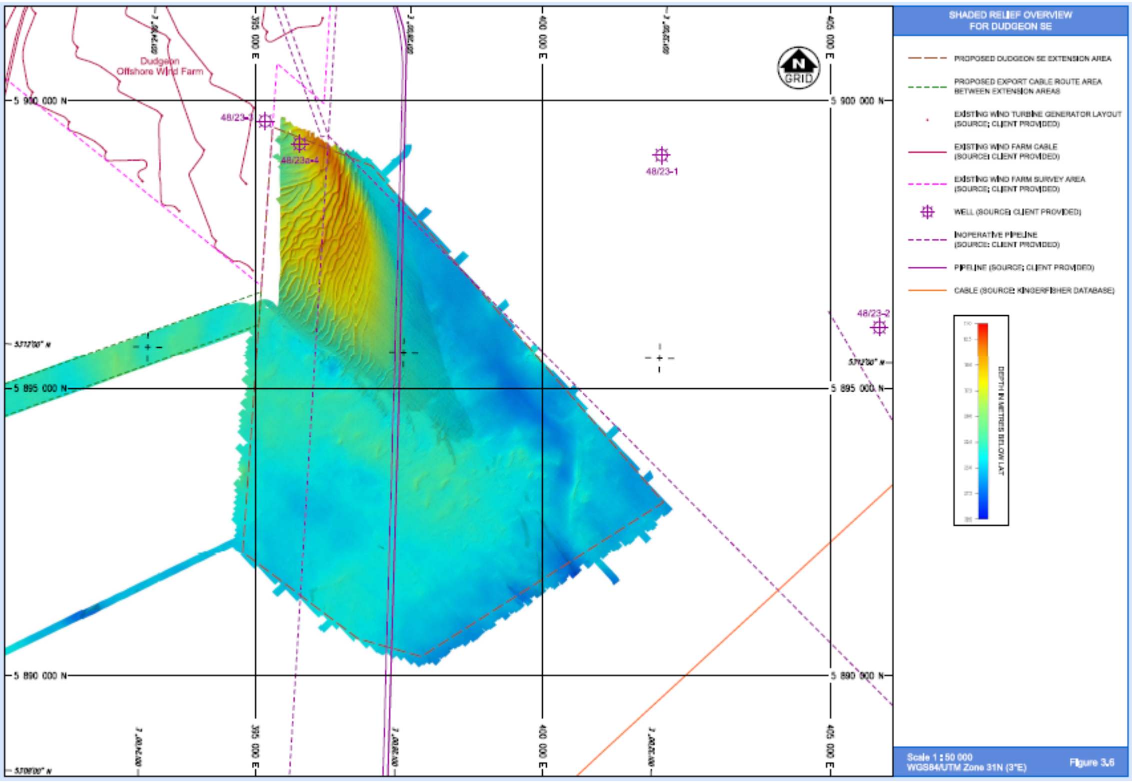

Figure 4 Bathymetry of the sandwaves across Inner Cromer Knoll Bank at the northwest corner of the DEP South array area

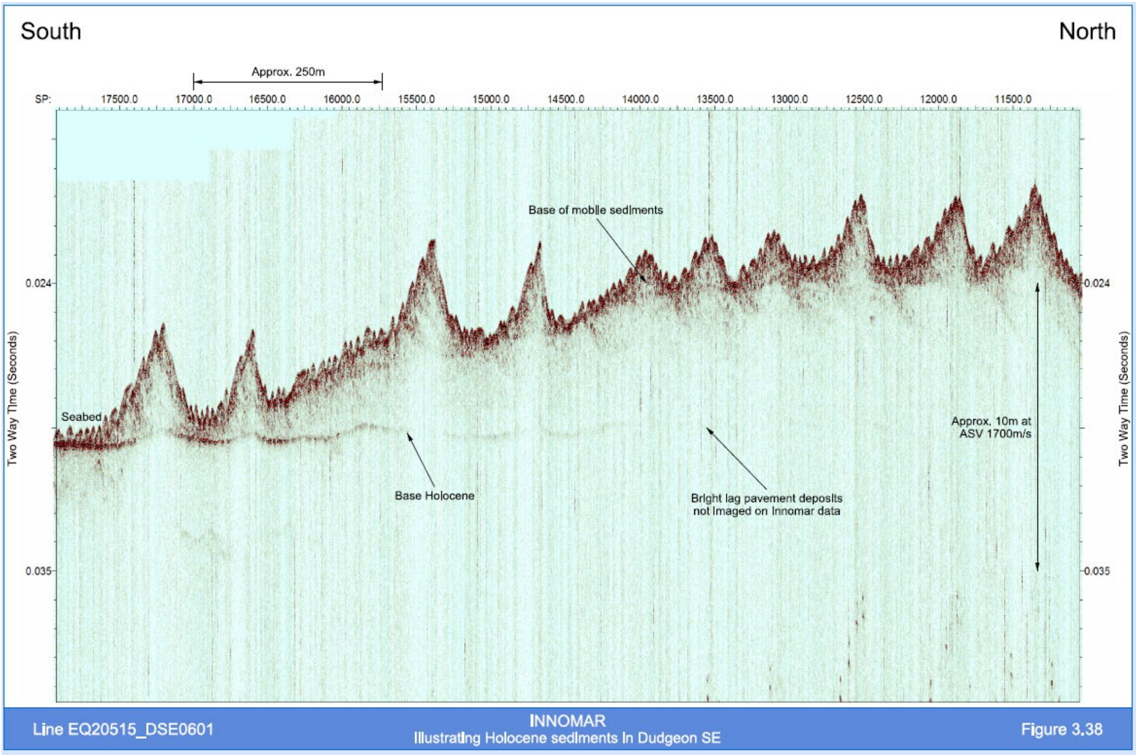

Figure 5 Sub-bottom profiler example of the sandwaves across Inner Cromer Knoll Bank at the northwest corner of the DEP South array area

2.1.2.3 Sheringham Shoal

15. The eastern tip of Sheringham Shoal Bank is inside the export cable corridor about 10km from the coast of north Norfolk. Here the bathymetry of the bank is about 16m below LAT (Gardline, 2019) (Figure 6). The crest of the bank is 8-14m thick inside the cable corridor (Figure 7 and Figure 8) but is much thicker to the west outside the cable corridor. It is covered in a field of megaripples, which are up to 0.5m high with wavelengths up to 16m, and crests typically oriented north-south or north-northeast to south-southwest (Gardline, 2019). The northern flank contains sandwaves with heights of about 3-4m, wavelengths up to 150m, and crests oriented approximately north-northeast to south-southwest (**Figure 9**). They are asymmetrical with their steeper sides facing east-southeast implying migration in the same direction.

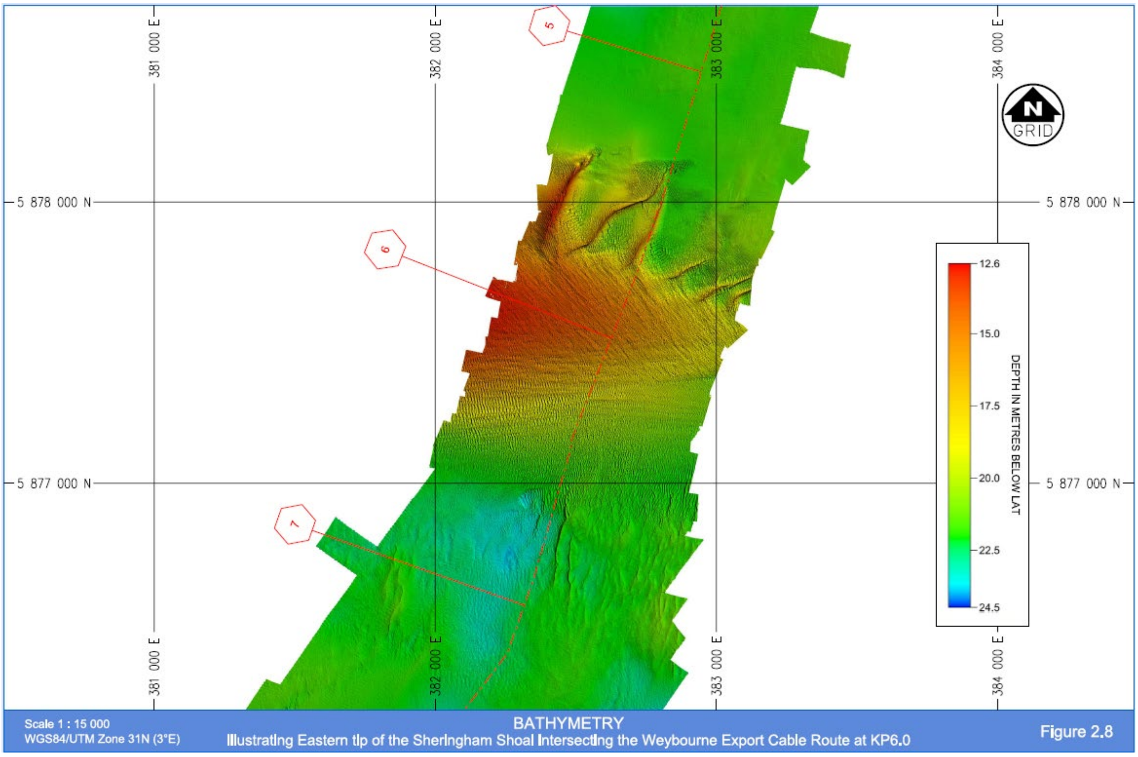

Figure 6 Bathymetry of the eastern tip of Sheringham Shoal Bank inside the export cable corridor

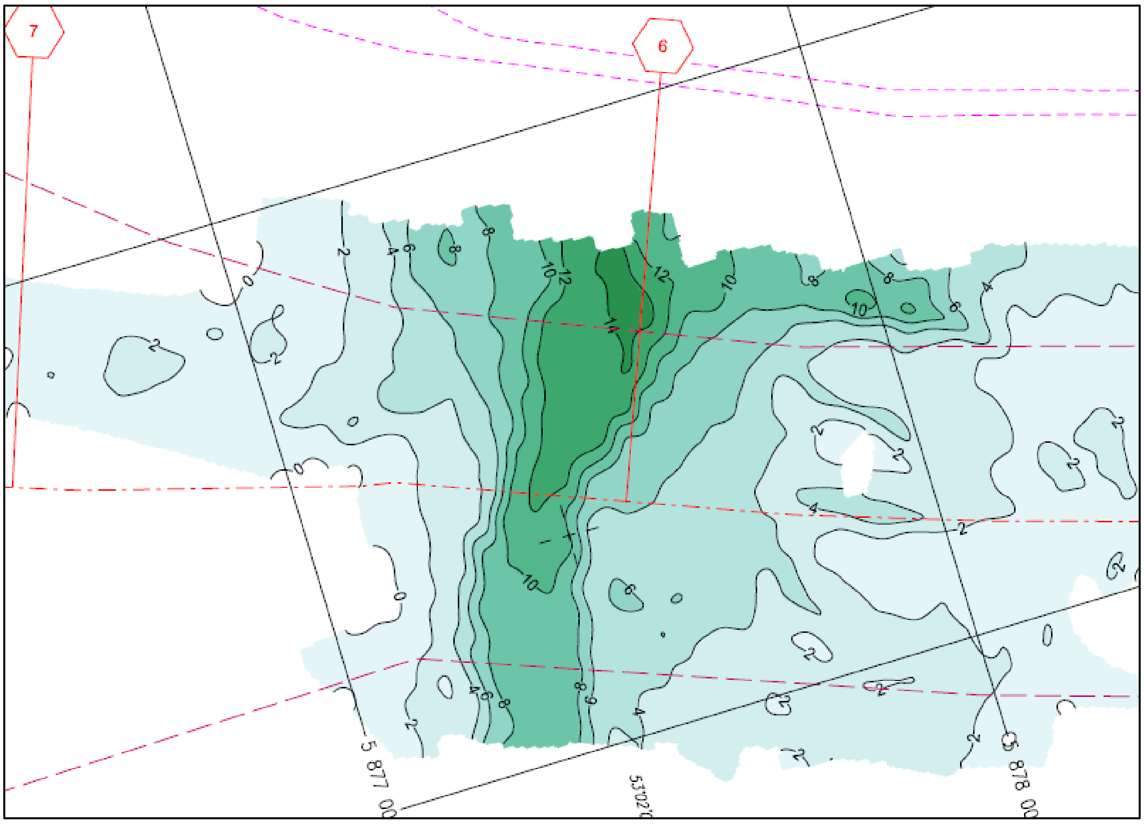

Figure 7 Thickness of the eastern tip of Sheringham Shoal Bank inside the export cable corridor

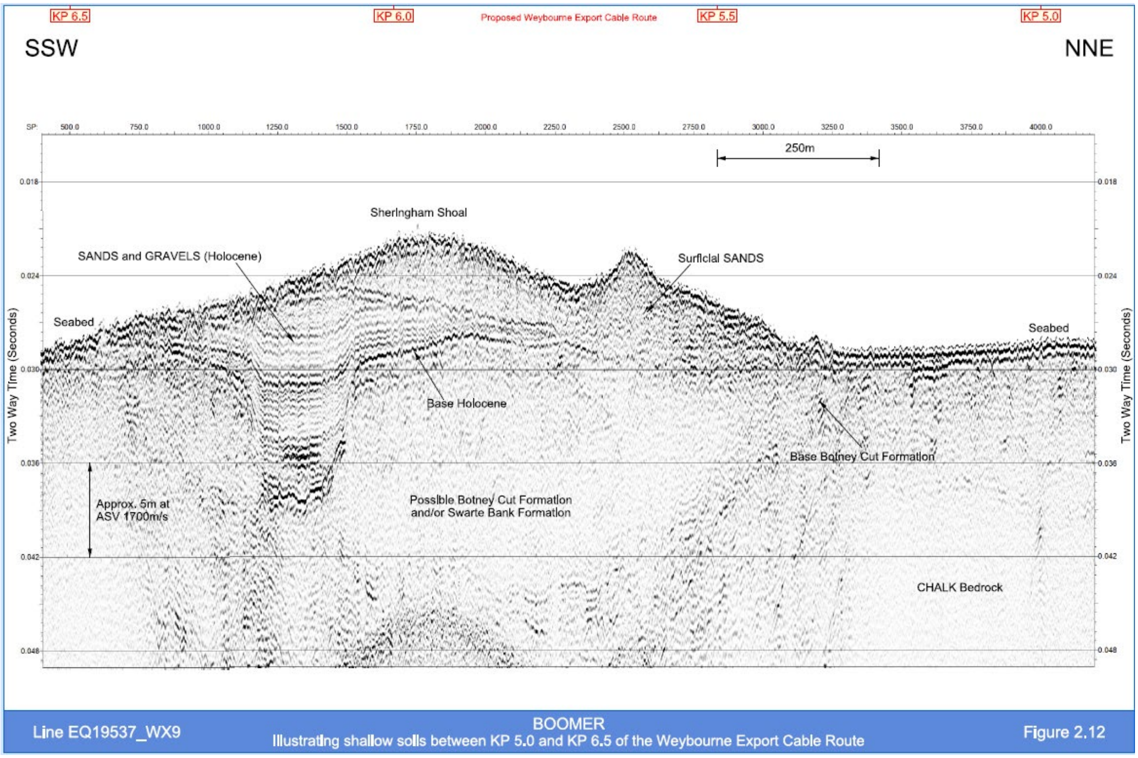

Figure 8 Sub-bottom profiler example across the eastern tip of Sheringham Shoal Bank inside the export cable corridor

2.1.2.4 Pollard Bank

16. Pollard Bank is about 3km offshore and is located to the west of the export cable corridor. The crest of the bank is about 8m below LAT. The approach to the southern flank is sculpted into southwest-northeast crest-aligned megaripples and sandwaves which are up to 1.6m high. The maximum thickness of sand in the bank is about 6m. The bank is asymmetric with the northern flank having a gentler slope than the southern flank implying migration south. The northern flank contains megaripples with crests oriented southwest-northeast. Pollard Bank disappears to the east and is not present inside the export cable corridor.

17. Fugro EMU (2016) compared 2015/2016 and 2008 bathymetry data across Pollard Bank. Migration of sandwaves over this seven-to-eight-year period is manifest as alternating areas of erosion (up to 1.3m) and accretion (up to 1.7m) (Figure 5.10 of ES Appendix 6.3 [APP-182]). Fugro (2019) also compared 2018 and 2008 bathymetry data. Seabed change occurred across Pollard Bank, with elevation changes of -1.3m (erosion) to +2.0m (accretion) (Figure 5.11 of Appendix 6.3).

2.1.2.5 Implications for Assessment

18. **Sections 2.1.2.1** to **2.1.2.4** above provide additional detail on the baseline characterisation of the bedforms across the array areas and interconnector cable corridors. The information supports the conclusion that in these areas, the seabed is dynamic and large-scale movement of sandwaves is occurring. There is no historic bathymetry data available from which rates of movement can be quantified,

but evidence from sandwaves in DOW (located on the same sandbanks, see **Section 2.5**) indicate that average migration rates could range from 2.5m/year to 3.5m/year, with periods of accelerated migration up to 10m/year. This evidence of regional-scale change at SEP / DEP alongside evidence from pre- and post-construction monitoring at Race Bank and a sand wave study carried out for the Norfolk Vanguard and Norfolk Boreas Projects, reinforces the assessment in Section 6.6.4.9 of the ES [APP-092] that sandwaves in this area are mobile under natural conditions and would recover from any proposed levelling through re-establishment of sand transport pathways. This will be aided by the disposal of the dredged sand back on to the sandbank (as is proposed), allowing it to be become re-entrained in the sediment transport system.

2.2 Baseline Tidal Ellipses

19. There are two related Natural England comments on the need to provide a visualisation of tidal ellipses across the wind farm. These are included below for ease of reference.

2.2.1 Natural England Comments at ID 6, and ID 23

20. *ID 6: In addition, there does not appear to be a map showing the spring tidal ellipses across the study area.*

21. *ID 23: Natural England notes that the neap and spring tidal excursions have not been provided. The spring tidal excursion is useful for estimating the potential extent of direct changes to flows as well as the anticipated maximum zone of influence for sediment plumes. We advise that the Neap/spring tidal excursions should be quantified in an updated chapter. It would also be useful to provide a map showing the spring tidal ellipses across the study area.*

2.2.2 Response

22. The spring tidal ellipses across the study area are provided in **Figure 9** below. The ellipses provide an indication of the maximum extent to which a particle of sediment in the water column could travel. However, given the relatively coarse nature of the sediment across the array sites, the small magnitude of the plume of fine sediment would mean that most particles would not achieve this maximum extent, as they would settle to the seabed a shorter distance from their release point (up to a kilometre along the axis of tidal flow) rather than travelling to the full extent of the ellipse. However, the lowest suspended sediment concentrations would extend further from the point of release, along the axis of predominant tidal flows (long axes of the ellipses), but the magnitudes would be indistinguishable from background levels.

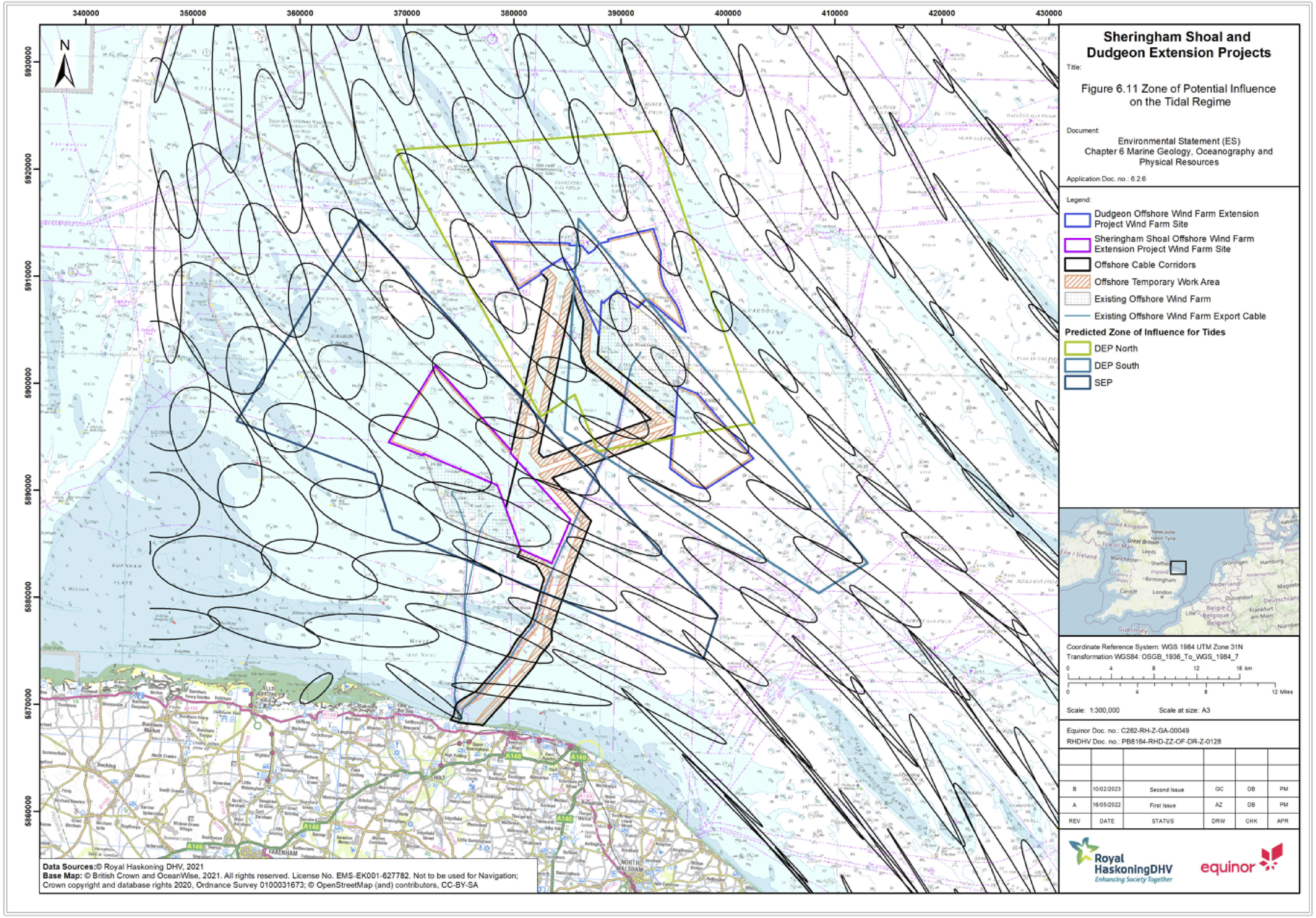

Figure 9 Zone of Potential Influence on the Tidal regime and spring tidal ellipses

2.3 MPAs and the Zone of Potential Tidal Influence

23. There is a single comment on the need to superimpose marine protected areas on the maximum zone of potential influence map (Figure 6.11 of the ES [APP-119]). This comment is included below for ease of reference.

2.3.1 Natural England Comment at ID 47

24. ID 47: *Point 316. The maximum zone of potential influence (ZoPI) on the tidal regime is presented in Figure 6.11, which we welcome. However, marine protected areas have not been identified on this map. It would be useful to identify marine protected areas on Figure 6.11 to show where they overlap with the ZoPI.*

2.3.2 Response

25. The updated Figure 6.11 is provided as **Figure 10** below. With respect to the overlap shown with the Inner Dowsing, Race Bank and North Ridge Special Area of Conservation (SAC), the potential increased suspended sediment concentrations (SSC) and deposition effects during construction, operation and decommissioning; and changes to physical processes resulting in changes to sediment supply (i.e. sediment transport effects) during operation (but in relation to the SEP wind farm site only), are assessed within the **Report to Inform appropriate Assessment (RIAA)** [APP-059].

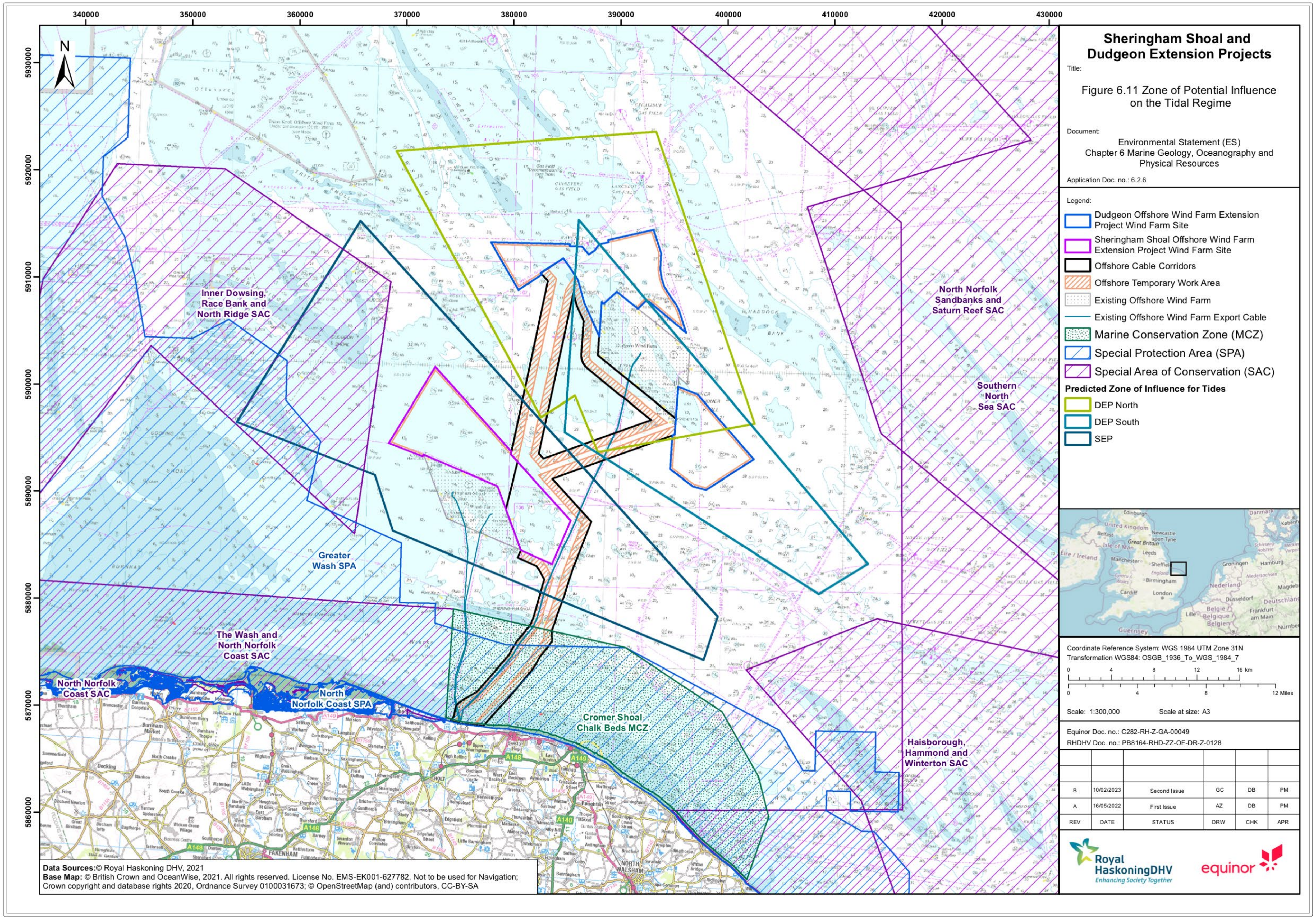

Figure 10 Zone of Potential Influence on the tidal regime in the context of marine protected areas

2.4 Potential Impacts on Suspended Sediment Concentrations

26. There are four related comments on the need to provide more detail on the assessment of effects on suspended sediment concentrations. These are included below for ease of reference.

2.4.1 Natural England Comments at ID 37, ID 38, ID 39, and ID 40

27. *ID 37: Points 239-241. The SOW and DOW-based model simulation quantification of magnitude of change are useful analogues for the SEPDEP export cable for sediment disturbed by export cable installation. However, it is not clear if/how the SOW/DOW max temporary disturbance widths for export cable installation and burial, or amount of sediment disturbed compare with those for SEP/DEP. This should be clarified. Furthermore, in Point 239, it is stated that although SSCs will be elevated they are likely to be lower than concentrations during storm conditions (including the Dec 2013 storm surge), which are likely to drive greater changes to the seabed than those due to the OWF infrastructure. Natural England advises that within an updated chapter it should be shown how the SOW/DOW trench size and amount of disturbed sediment compare with those for SEP/DEP. Quantitative evidence should be provided to support the predictions regarding SSCs.*

28. *ID 38: Point 245. It is noted that elevated SSCs above prevailing conditions are anticipated at the HDD exit point, but that they are also likely to remain within the range of background nearshore levels. This conclusion should be supported with quantitative estimates. Please see comment above.*

29. *ID 39: Points 255 & 256. Results from the sediment dispersion modelling for the SOW and DOW export cables (Points 170 & 171 in Chapter 6), suggest that suspended load for disturbed mud would extend as a plume over <2km for SOW, and <1km for silt in either direction. However, as noted above, there is no information on the max disturbance width or amount of sediment disturbed due to cable installation at DOW/SOW, compared with those at DEP/SEP. Please provide further clarification within an updated chapter.*

30. *ID 40: Point 255. Given that the [export cable corridor] ECC traverses the [Cromer Shoal Chalk Beds] CSCB MCZ, it would be very helpful if the plume model data for SOW/DOW could also be provided as predicted deposition footprints for representative locations between the HDD exit location and seaward boundary of the MCZ. These should be representative of the different sedimentary zones along the ECC within the MCZ and also include the HDD exit location. Furthermore, it is not stated what the estimated deposited sediment thickness may be for the different sediment fractions (i.e. fine/medium/coarse) due to export cable installation. Modelled deposition footprints and thickness should be provided for locations representative of the different sedimentary zones along the ECC within the MCZ and include the HDD exit location. Can estimated deposited sediment thickness be provided for the different sediment fractions?*

2.4.2 Response

31. Scira (2006) completed sediment dispersion modelling to define the extent of plume dispersion due to SOW export cable installation and the extent of the depositional

footprint. Given the similar positions of the SOW export cable corridor and the SEP and DEP export cable corridor, the modelling of the SOW installation was considered a suitable analogue for the potential effect of the installation of the SEP and DEP cables.

32. Scira (2006) defined the following parameters for the plume dispersion modelling for SOW:

- cable burial depth of 1m;
- 0.3m^3 of sediment disturbance per metre run; and
- sediment size distribution of less than 4% fines.

33. Table 6-2 of the ES [APP-119] indicates that at SEP and DEP, the following trench sizes and sediment disturbance volumes were assessed for export cables:

- cables buried up to 1m below the seabed using an indicative sediment displacement width of 1m and a v-shaped trench;
- cable lengths of 62km for DEP and 40km for SEP;
- displaced sediment of 31,000m^3 for DEP and 20,000m^3 for SEP;
- mud content less than 5% outside the MCZ and mostly 0% inside the MCZ.

34. Translating these absolute volumes for SEP/DEP to sediment disturbance per metre run equates to 0.5m^3 per metre of export cable. This is approximately 1.6 times higher than the volume modelled for sediment dispersion for SOW.

35. **Figure 11** and **Figure 12** illustrate the results of the sediment dispersion modelling for the SOW export cable based on the parameters described by Scira (2006). They describe the footprint of dispersion that represents the peak increase of suspended sediment experienced at each point in the model domain over the full duration of the simulation. The minimum contour value is a 1mg/l increase as it is assumed that any value below this is negligible in relation to the background situation.

36. They show that the neap tide footprint is predicted to extend less than 2km, while the spring tide footprint is very small. The neap tide footprint is larger due to the lower rate of turbulent diffusion. If the extent of the footprint and magnitude of concentrations are upscaled by 1.6 times to account for the difference in sediment disturbance volumes between SEP/DEP and SOW, then the spread would be less than 3.6km on a neap tide and remain very small on a spring tide. Suspended sediment concentrations are likely to be higher, but would only be less than 10mg/l, conservatively.

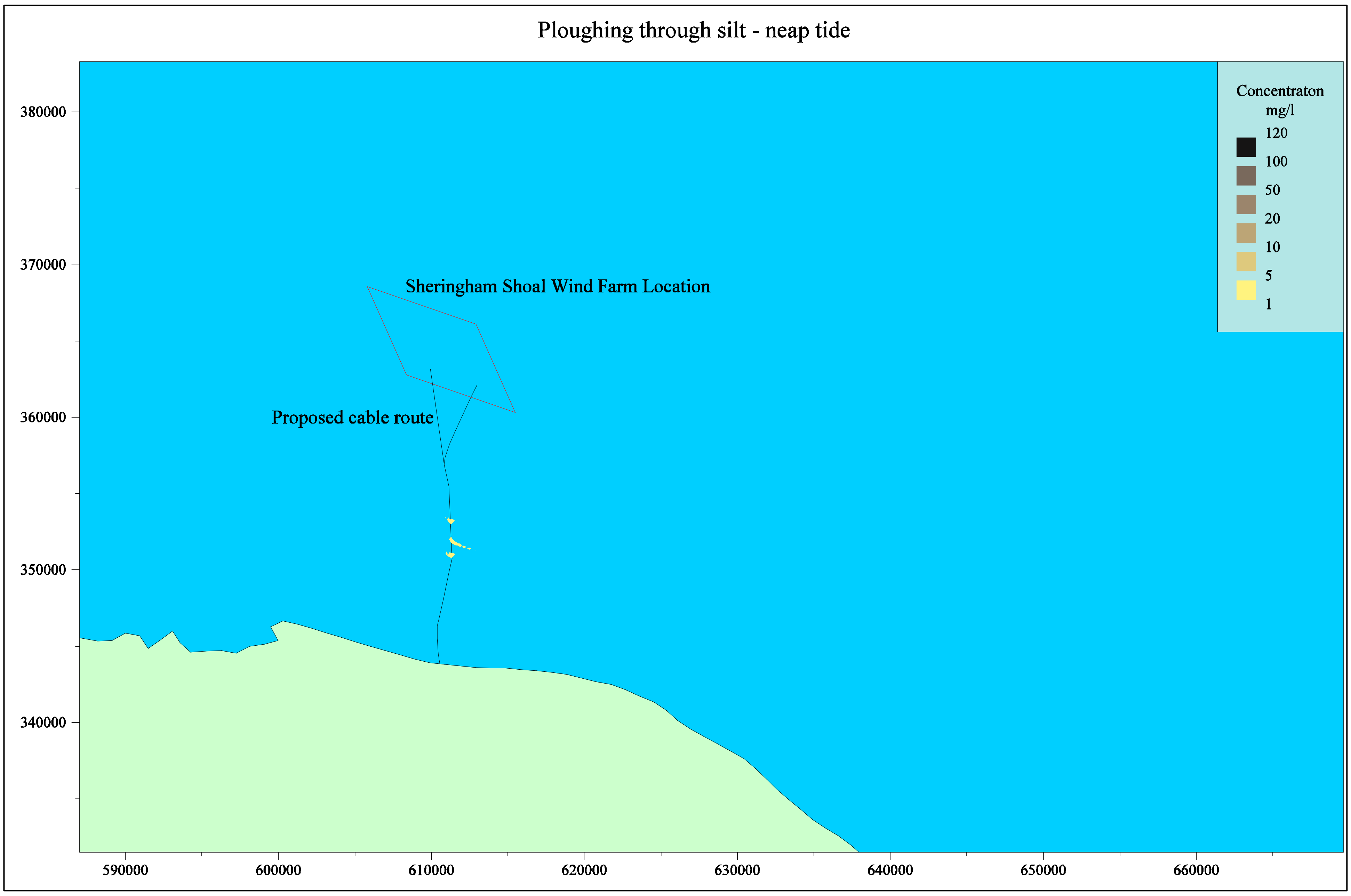

Figure 11 Predicted suspended sediment plume during a neap tide

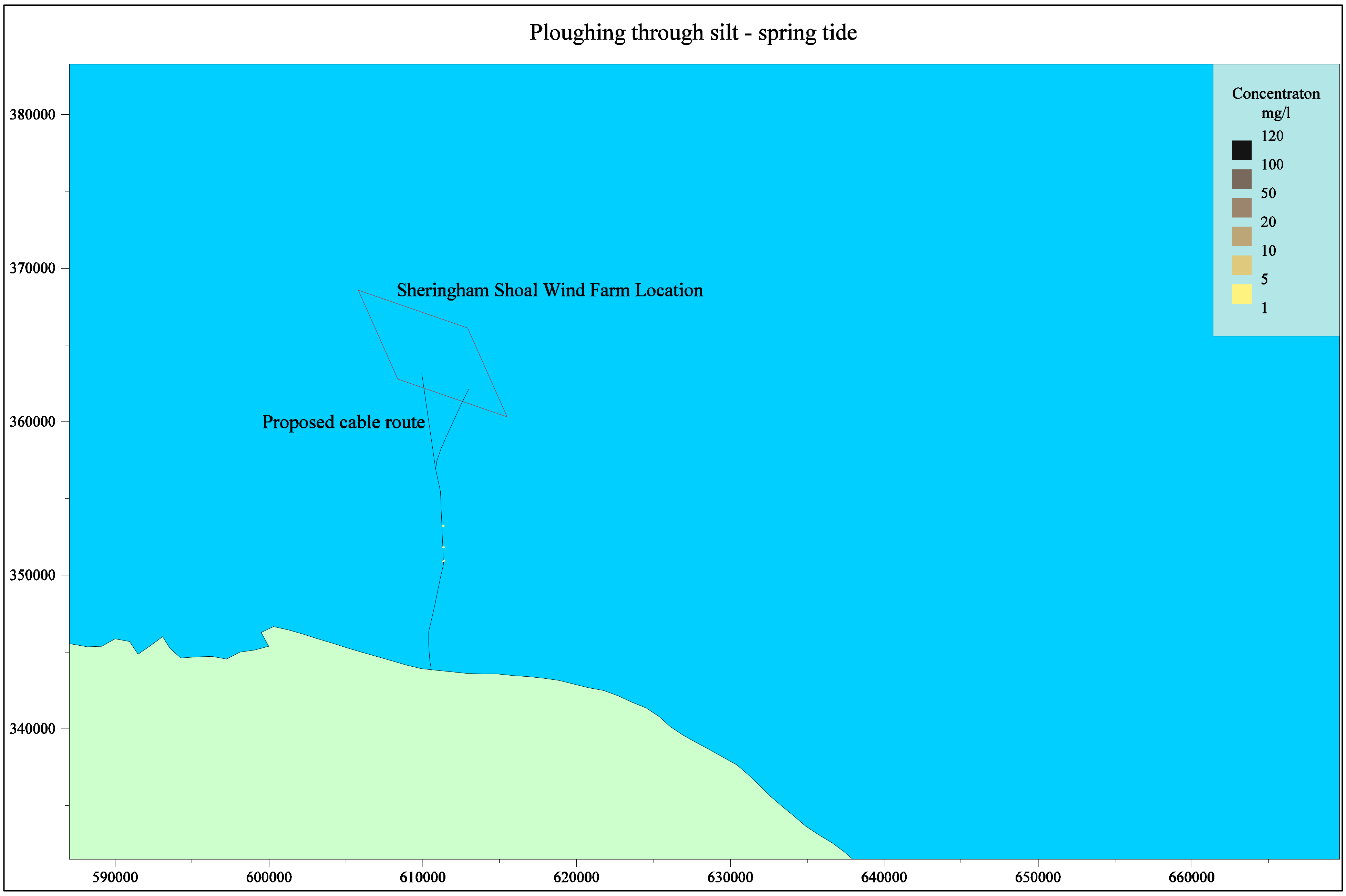

Figure 12 Predicted suspended sediment plume during a spring tide

37. In terms of the comparison of mud content, the SOW modelling is conservative (using 4%) compared to SEP/DEP because most samples inside the MCZ along the SEP/DEP export cable corridor do not contain any mud (the values are equivalent outside the MCZ).

38. Scira (2006) indicated that the predicted footprint of silt deposition extended over a wide area, but at an undetectable rate. Even under slack water conditions, the maximum rate of deposition over the six-tide simulation was less than 0.5mm in the areas of greatest deposition, and in most of the footprint area the rate was far less. This result is anticipated as the deposited fines will be re-suspended on each tide, with no measurable sediment left in place. No contour plots were presented.

39. If the predicted sediment thickness is increased to account for the difference in sediment disturbance volumes between SEP/DEP and SOW, then it would still be less than 0.8mm thick as a maximum and would be re-suspended on each tide. The time taken to reach a situation where there is no measurable sediment left on the seabed would take slightly longer to achieve.

2.5 Local Changes to the Seabed Bathymetry at DOW Post Construction

40. There are two related comments on the need to provide additional post-construction geophysical monitoring evidence of minimal changes to seabed bathymetry at DOW. These are included below for ease of reference.

2.5.1 Natural England Comments at ID 6 and ID 52

41. *ID 6: In addition, there does not appear to be DOW geophysical survey data to support conclusions that construction-related effects were minor and localised and that the seabed topography has not changed greatly.*

42. *ID 52: Point 337. Geophysical survey data from the existing OWFs are useful. However, it is stated that the DOW geophysical survey shows that only minor and localised effects remain from the wind farm construction, and that the 'overall topography of the seabed within DOW has not greatly changed'. However, it does not state when this survey was undertaken, nor what the minor and localised effects might be that remain, nor how the seabed is not greatly changed and since when. This should be made clearer as it is too vague to provide any useful comparison with SEPDEP. Furthermore, does the post-construction survey show any evidence of change to sandbank morphology or migration rate across DOW?*

2.5.2 Natural England Comments on Deadline 2 Submission

43. *We welcome the additional evidence provided by the Applicant from the comparison of pre- and post-construction geophysical surveys for Dudgeon Offshore Wind Farm (DOW). We agree that there appears to have been little change in overall seabed depth between 2013 and 2018 appears. However, given that the DOW array was only completed in 2017, it is not possible to establish any long-term trends in seabed morphological change based on the data presented in the Technical Note.*

44. *The DOW array sandwave migration analysis (2007-2018) is extremely useful. However, of the six sites analysed, results from only three sites have been provided in this Technical Note. Of these, two sites show both a marked decrease in sandwave height and an increase in migration rate between 2017 (when the DOW*

array was completed) and 2018 (one year later). Therefore, we cannot agree with the conclusion in Point 46, that 'sandwave migrations are indicative of naturally occurring processes across the array site and are not driven by changes caused by DOW.' Further subsequent sandwave migration analysis would be required to support this conclusion.

45. *We do not agree with the conclusions in Section 1.5.2 or Section 2 regarding seabed bathymetry and bedforms. To establish long-term trends in the overall seabed bathymetry across the DOW array site would require comparison of further bathymetry datasets from different time periods to better inform quantification of trends in seabed erosion/accretion. Furthermore, in regard to, sandwave migration across the DOW array area, we advise that analysis of additional datasets from different time periods is needed to help establish whether bedform changes and migration rates are due to natural or anthropogenic drivers.*

2.5.3 Response

46. This response provides more detail on the evidence from the comparison of pre- and post-construction geophysical surveys.

47. MMT (2018) detailed the results of the year 1 post-construction geophysical survey performed from 15th August to 5th September 2018 at the Dudgeon Offshore Wind Farm, where the aim was to determine site topography, gradient, seabed mobility and seabed features compared to a number of surveys undertaken pre-construction. The geophysical information was collected using multibeam echosounder (bathymetry) and side scan sonar (seabed texture) in advance of an environmental survey.

48. MMT (2018) reported the results of a full site comparison between 2013 and 2018 and a sandwave migration analysis (between 2007 and 2018) across six sites within the DOW array area (**Figure 13**). **Figure 14** shows a difference plot between the 2013 and 2018 bathymetry datasets for the whole array. The data shows that, apart from the areas of mobile sandwaves, there has been little change in the overall seabed depth.

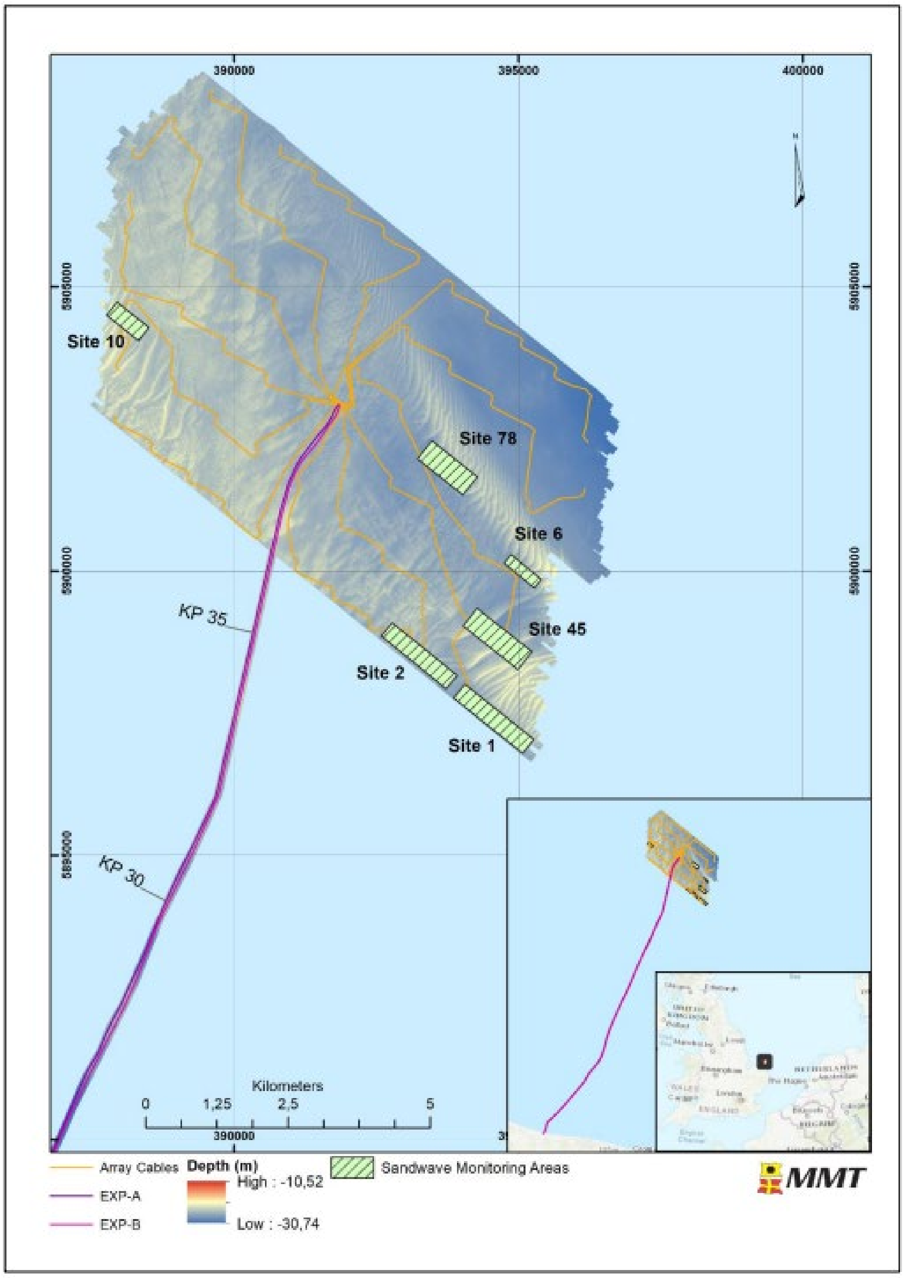

Figure 13 Locations of six sites for sandwave migration analysis within the DOW array area

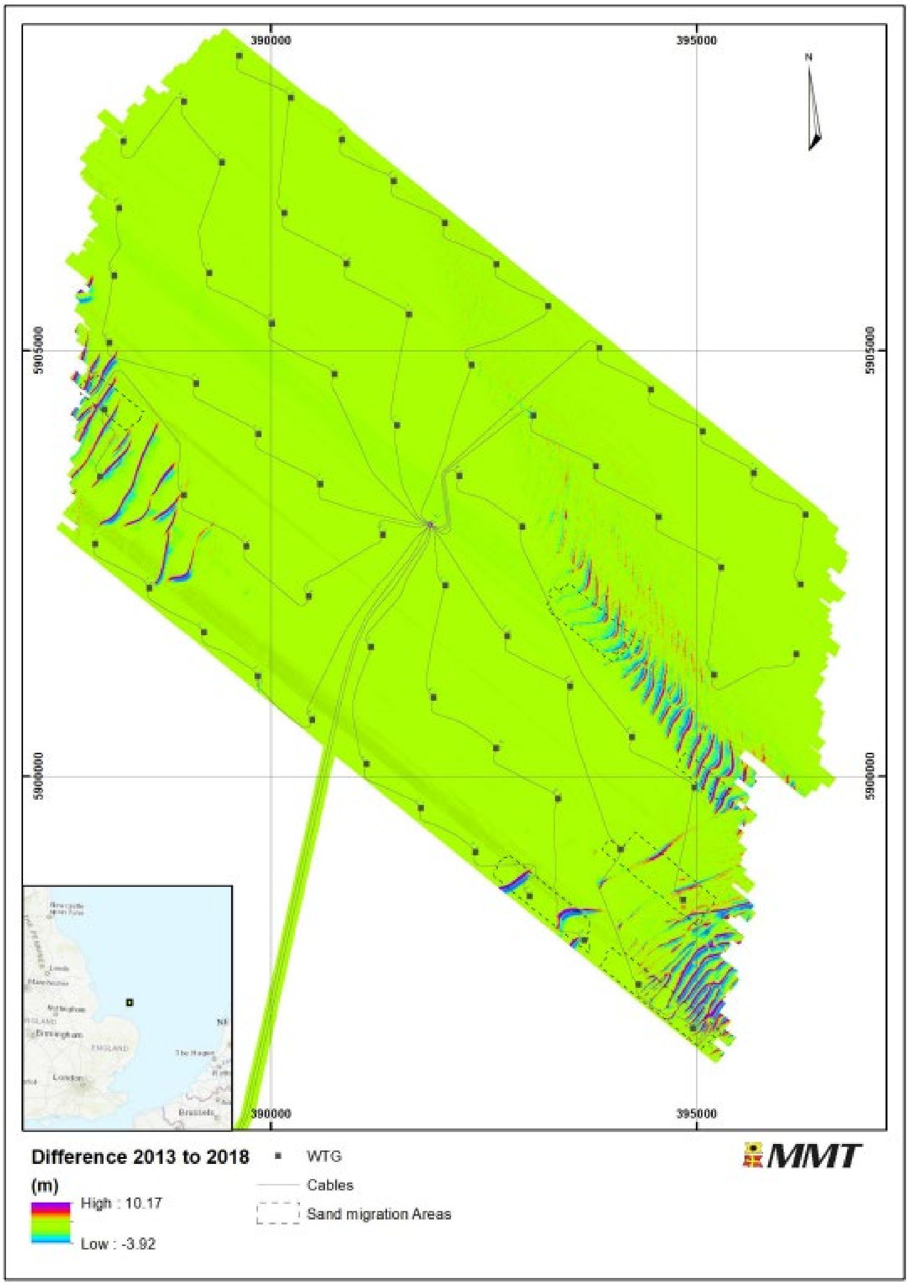

Figure 14 Difference in bathymetry between 2013 and 2018 across the DOW array area

2.5.3.1 Sandwave Monitoring Site 1

49. Site 1 is in the southeast of the DOW array area (**Figure 13**) and includes turbines J04 and J05. In 2018, the crest heights of the sandwaves ranged from approximately 1m to 4.1m with wavelengths between 60m and 135m (**Figure 15**).

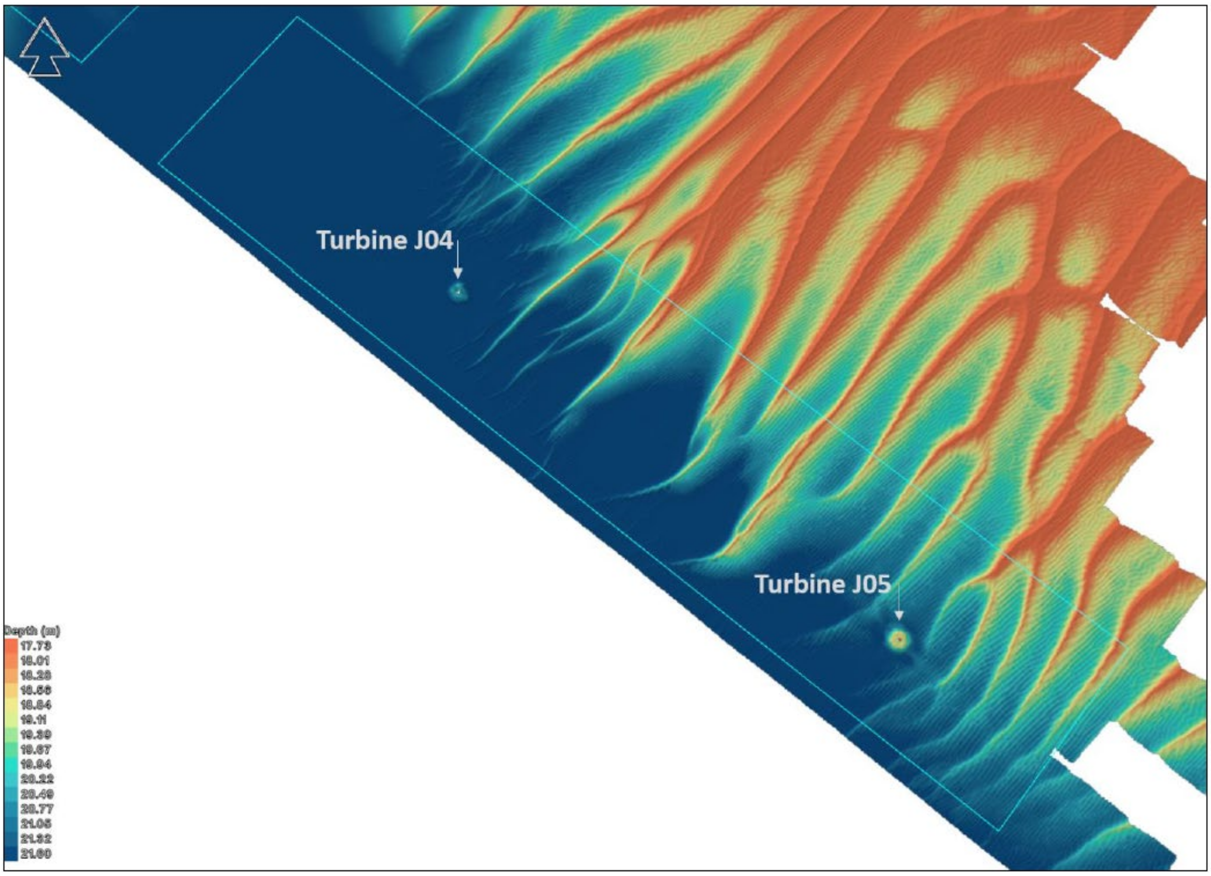

Figure 15 2018 bathymetry of Site 1 (DOW array area)

50. There have been significant changes within Site 1. The sandwaves are migrating to the northwest (**Figure 16**). The average rate of migration was 2.5m/year over the 11-year period from 2007 to 2018, with an accelerated rate of about 10m/year between 2017 and 2018.

51. **Figure 15** shows that turbines J04 and J05 are towards the edge of the sandwaves and have little interaction with the main bulk of the field, where the sandwaves are higher and established. **Figure 16** shows that across the established sandwaves, their heights have been consistent between 2007 and 2018.

52. The profile shown in **Figure 17** is towards the edge of the sandwaves where the probability of greater changes is higher. It shows that at the edge of the field a sandwave has changed shape, both over the longer-term (2007-2018) and shorter-term (2017-2018). It has fluctuated in height, lowering between 2007 and 2013, becoming higher again through 2015/2017 and then lowering again to 2018. Also, between 2017 and 2018, a new sandwave crest was generated. These changes are part of the natural development and evolution of sandwaves towards the edge of a sandwave field and are unrelated to the position of the turbine foundations (J04 is just outside the field and J05 is within a wide trough at the end of the field).

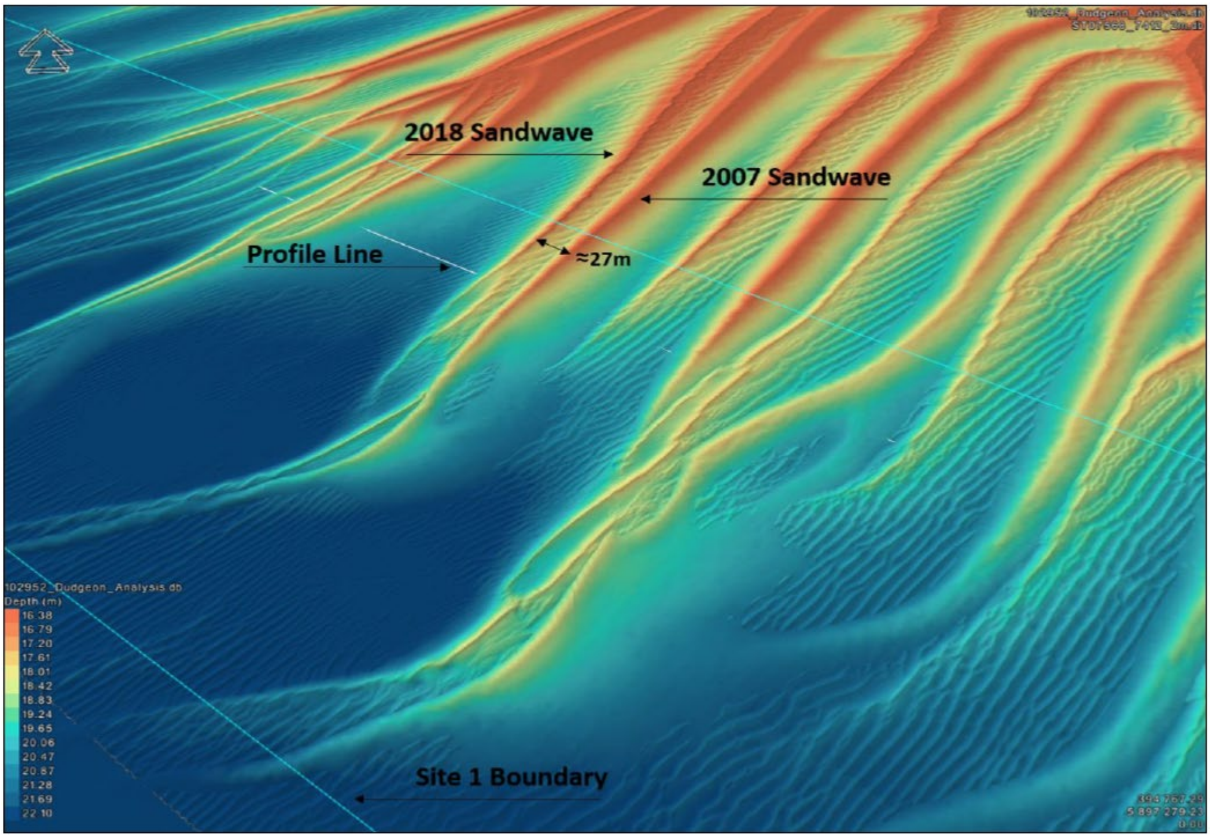

Figure 16 2018 data overlaid on the 2007 data for a part of Site 1

53. The profile towards the edge of the sandwave field is shown in

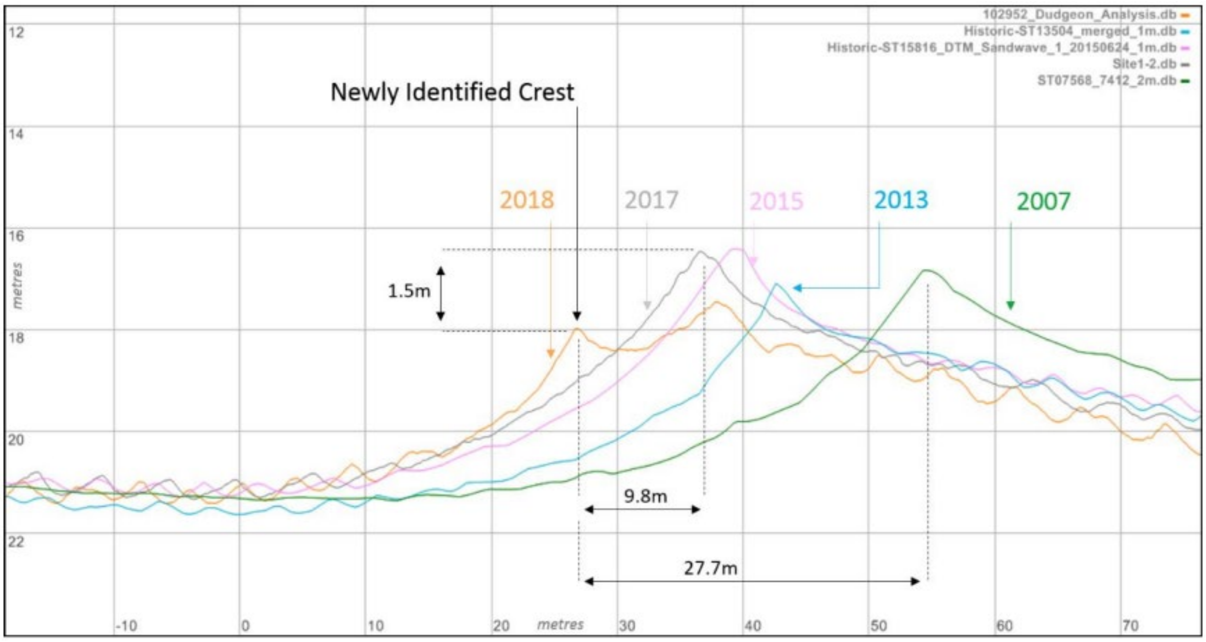

Figure 17 Site 1 seabed profile demonstrating sandwave migration (and bifurcation) over eleven years

2.5.3.2 Sandwave Monitoring Site 2

54. Site 2 is also in the southeast of the DOW array area (**Figure 13**), and covers two large isolated sandwaves with two adjacent turbine foundations, L05 and K05, in the wide troughs in-between (**Figure 18**). The crests of the sandwaves are approximately 3.3m high and about 650m apart (from crest to crest).

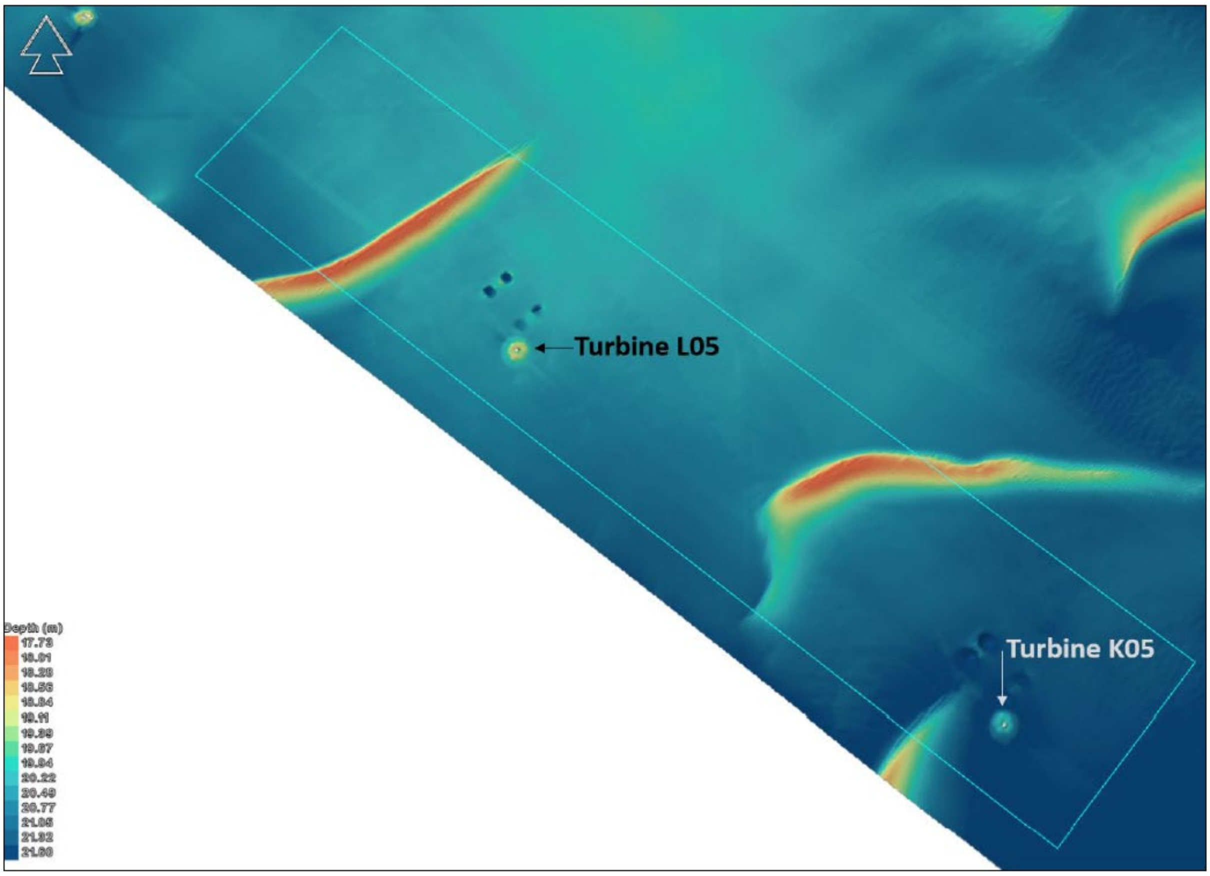

Figure 18 2018 bathymetry of Site 2

55. Comparison of the 2018 data with the 2007 data showed that both sandwaves migrated to the northwest (**Figure 19**). Between 2017 and 2018, both sandwaves migrated approximately 10m (**Figure 20**). The sandwave heights have varied slightly over time, but the 2018 heights are equivalent to the heights in 2007. Turbine foundations L05 and K05, are located at distance from these two isolated sandwaves and have had no effect on their evolution.

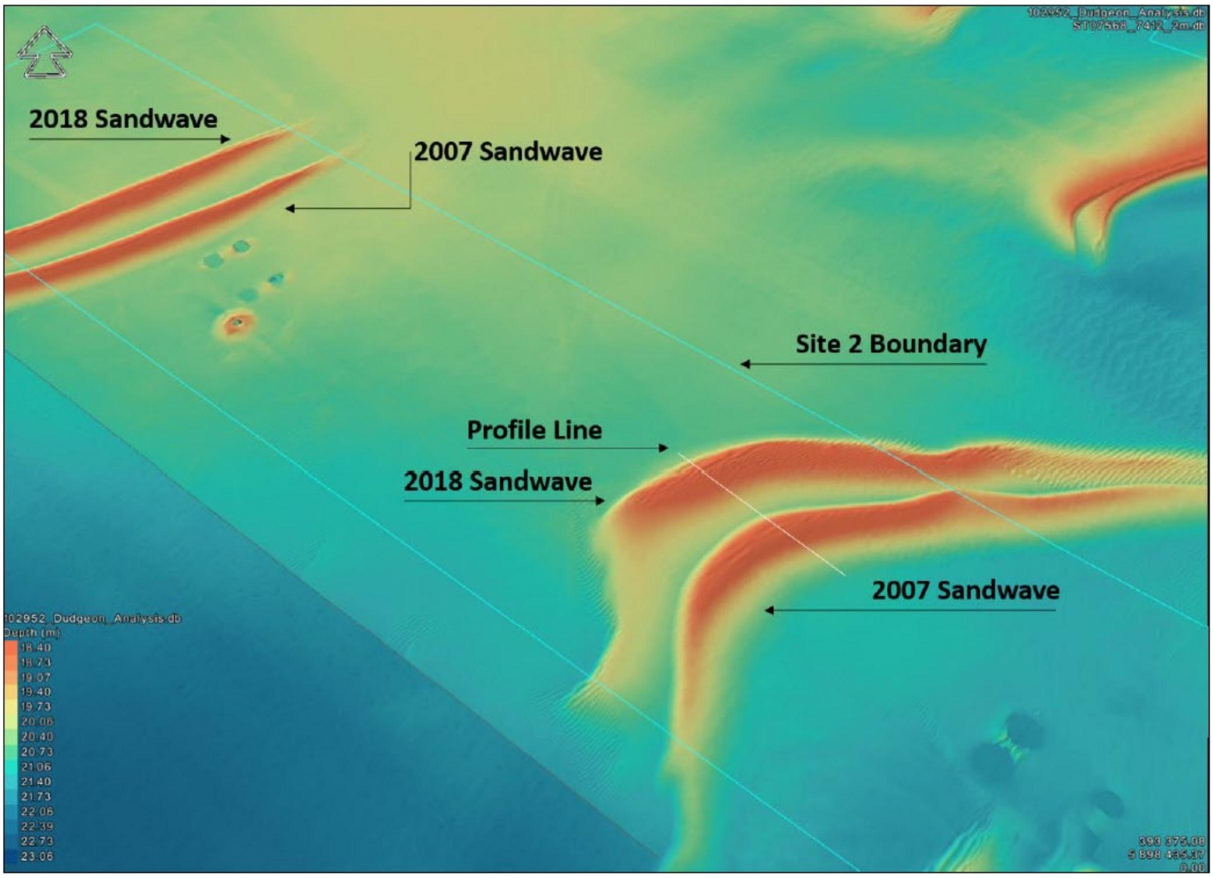

Figure 19 2018 data overlaid on the 2007 data for a part of Site 2.

56. The profile across the southeast sandwave is shown in Figure 20.

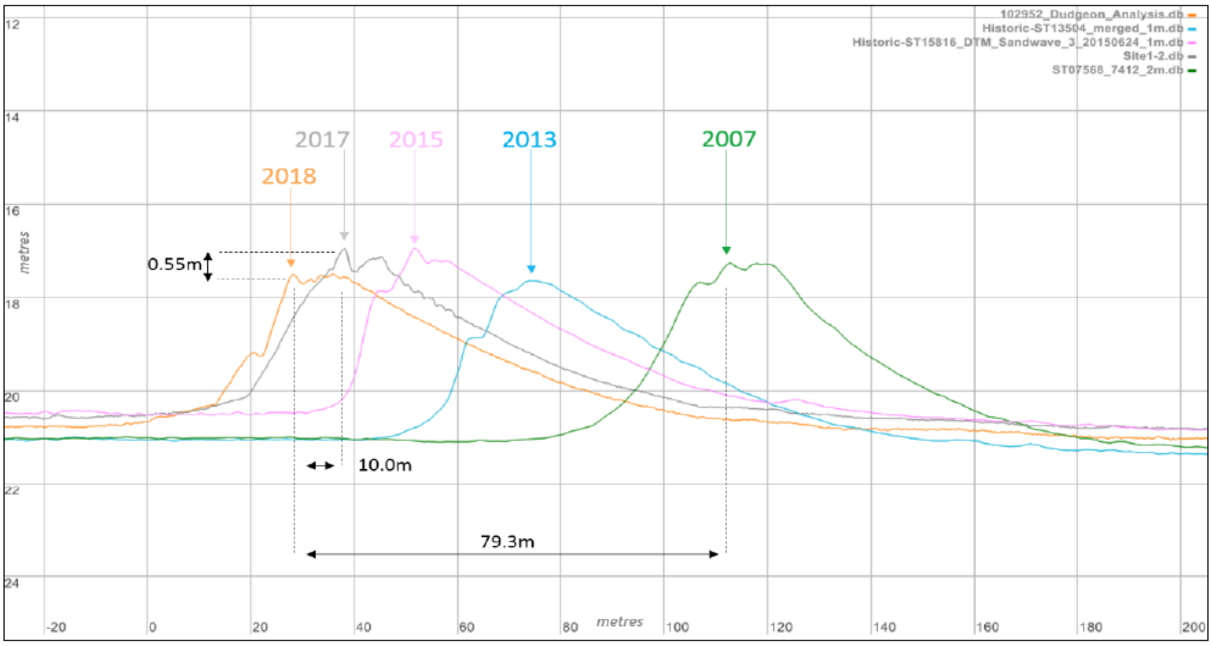

Figure 20 Site 2 seabed profile demonstrating sandwave migration over eleven years

2.5.3.3 Sandwave Monitoring Site 6

57. Site 6 is in the east of the DOW array area (**Figure 13**), north of turbine foundation T04 (**Figure 21**). There are five sandwaves with heights between approximately 2.3m and 3.2m, and wavelengths between approximately 115m and 160m.

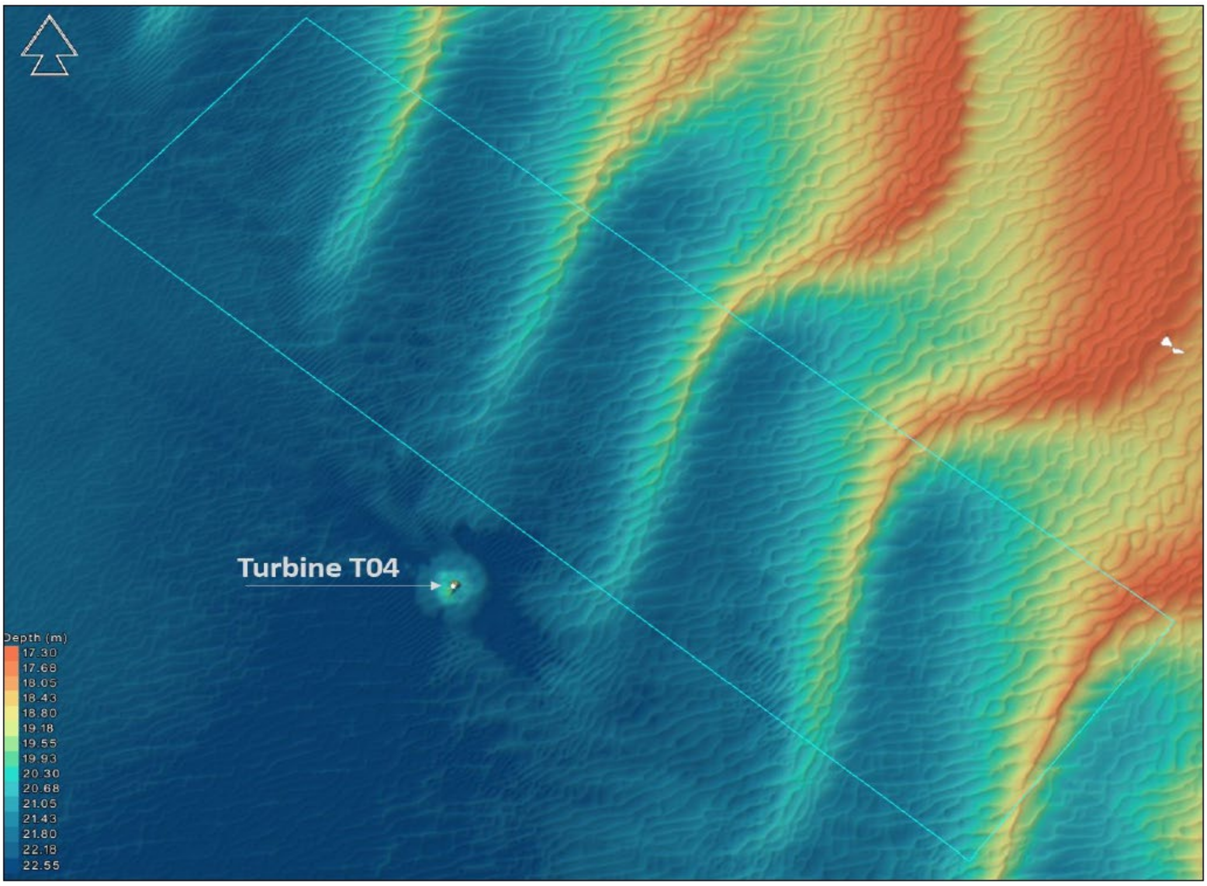

Figure 21 2018 bathymetry of Site 6

58. The sandwaves are migrating (predominantly) to the southeast (**Figure 22**). The average rate of migration was 3.5m/year over the 10-year period from 2007 to 2017. Between 2017 and 2018, there appears to have been a reversal in migration direction with a rate of about 4.5m/year to the northwest (**Figure 23**). The position of turbine foundation T04 at the periphery of the sandwaves means it has had no effect on their evolution.

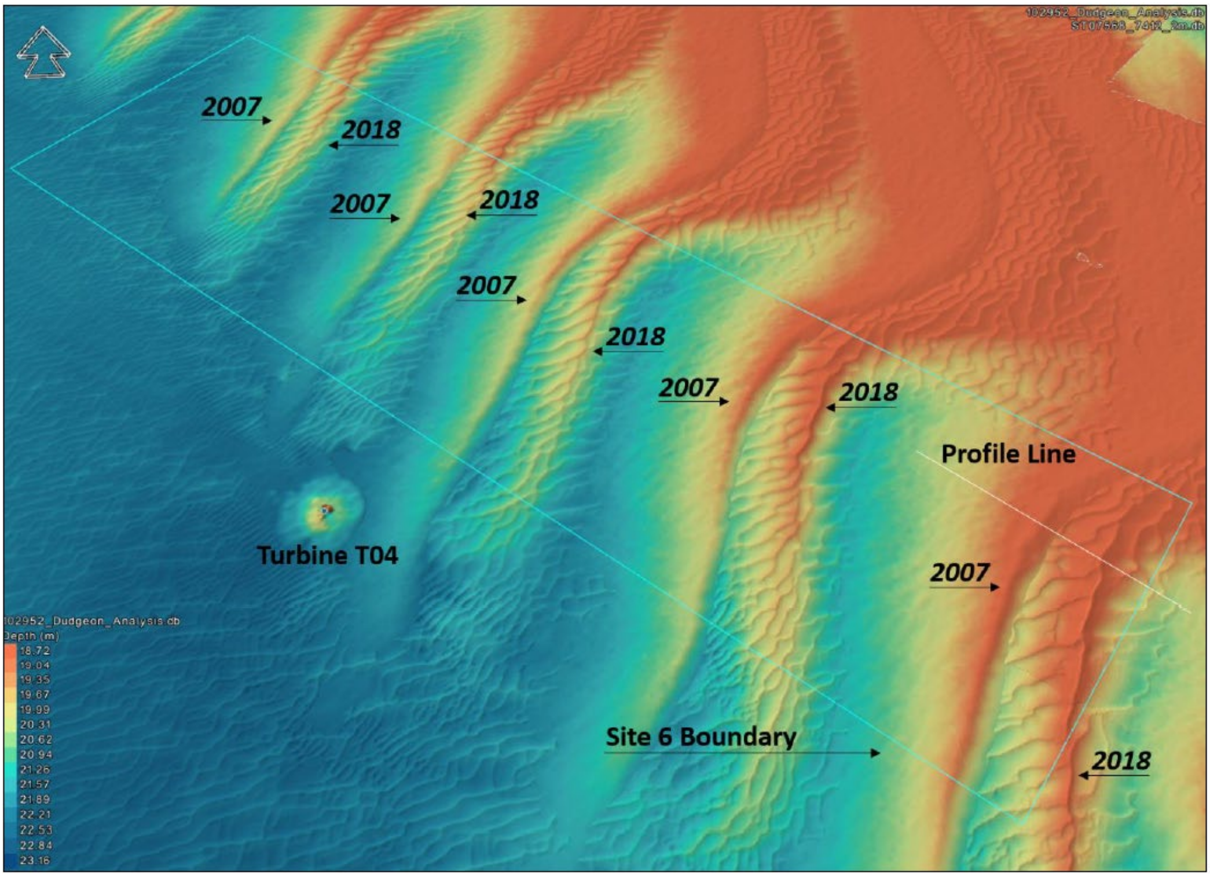

Figure 22 2018 data overlaid on the 2007 data for Site 6.

59. The profile across a sandwave is shown in Figure 23

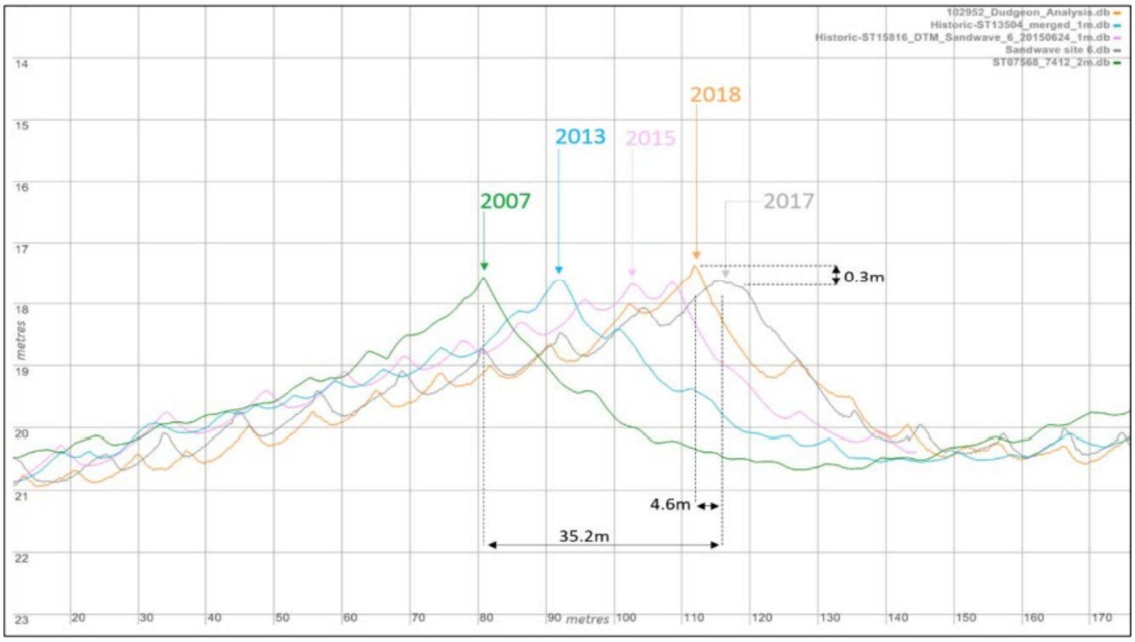

Figure 23 Site 6 seabed profile demonstrating sandwave migration over eleven years

2.5.3.4 Sandwave Monitoring Site 10

60. Site 10 is in the west side of the DOW array area (**Figure 13**). The site contains four sandwaves and is also the location of turbine B05 within the sandwave field (**Figure 24**).

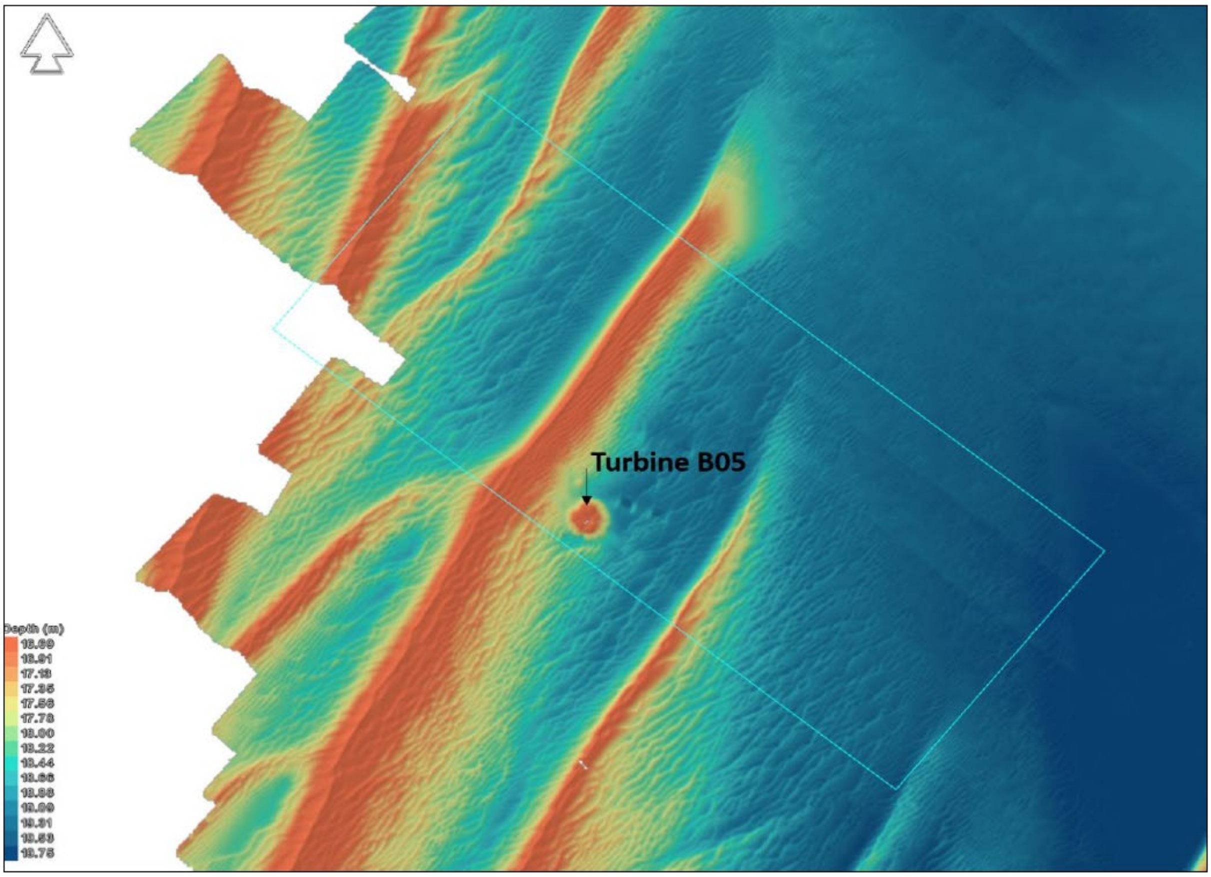

Figure 24 2018 bathymetry of Site 10

61. The sandwaves are migrating to the northwest (**Figure 25**). Rates of migration vary from an average of 3.5m/year over the 11-year period from 2007 to 2018, and an accelerated rate of about 6.5m/year between 2017 and 2018. **Figure 25** demonstrates that the planform profile of the sandwave northwest of turbine foundation B05 has been unaltered by the presence of the structure. Also, there has been development of microtopography (ripples) since 2013 and these have continued into 2018, regardless of the presence of the foundation.

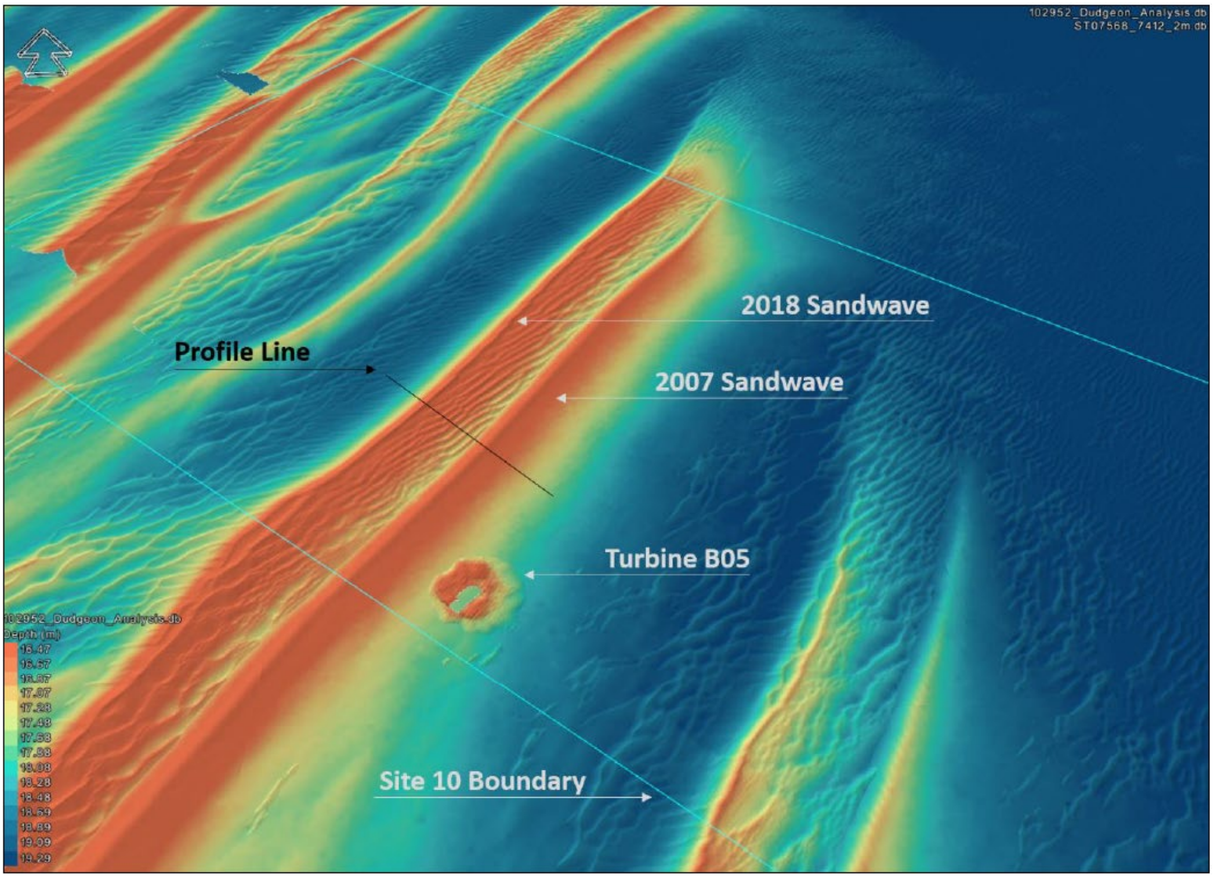

Figure 25 2018 data overlaid on the 2007 data for a part of Site 10

62. The profile across the sandwave field north of turbine foundation B05 is shown in **Figure 26**.

63. **Figure 26** describes a profile to the north of turbine foundation B05. It indicates that at this location the sandwave height was stable between 2007 and 2013, grew between 2013 and 2017, and then reduced in height between 2017 and 2018. However, the height in 2018 is equivalent to the height in 2007 and 2013, and the changes in height are part of its natural evolution, rather than being impacted by the structure.

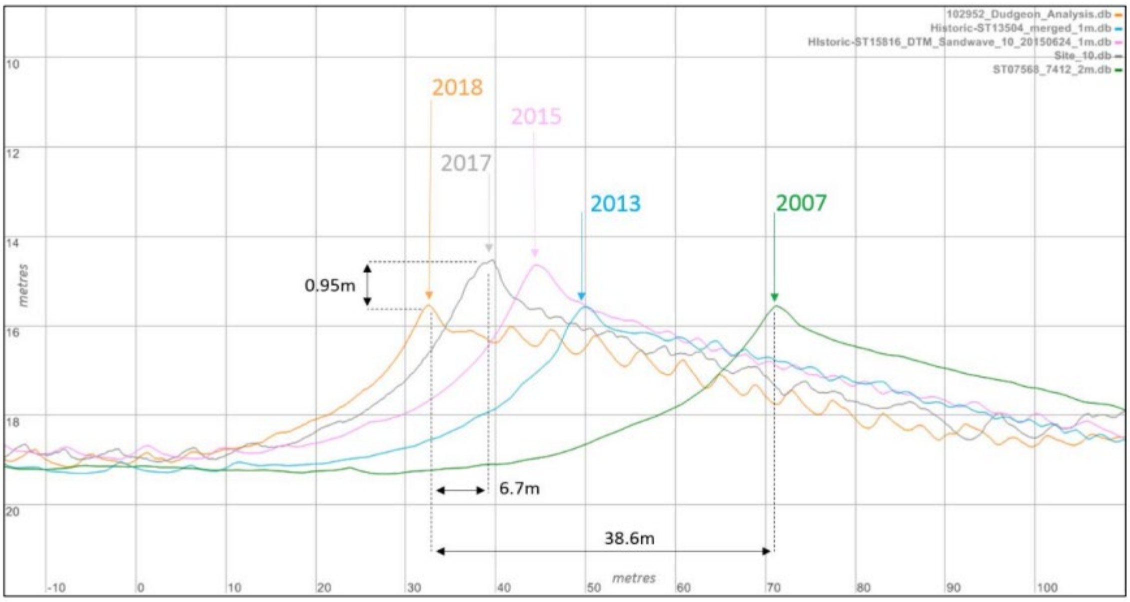

Figure 26 Site 10 seabed profile demonstrating sandwave migration over eleven years

2.5.3.5 Sandwave Monitoring Site 45

64. Site 45 is in the southeast of the DOW array area (**Figure 13**) and includes turbine foundations J03 and T05 (**Figure 27**). There are three large sandwaves, each with a crest height between approximately 4.6m and 5.8m.

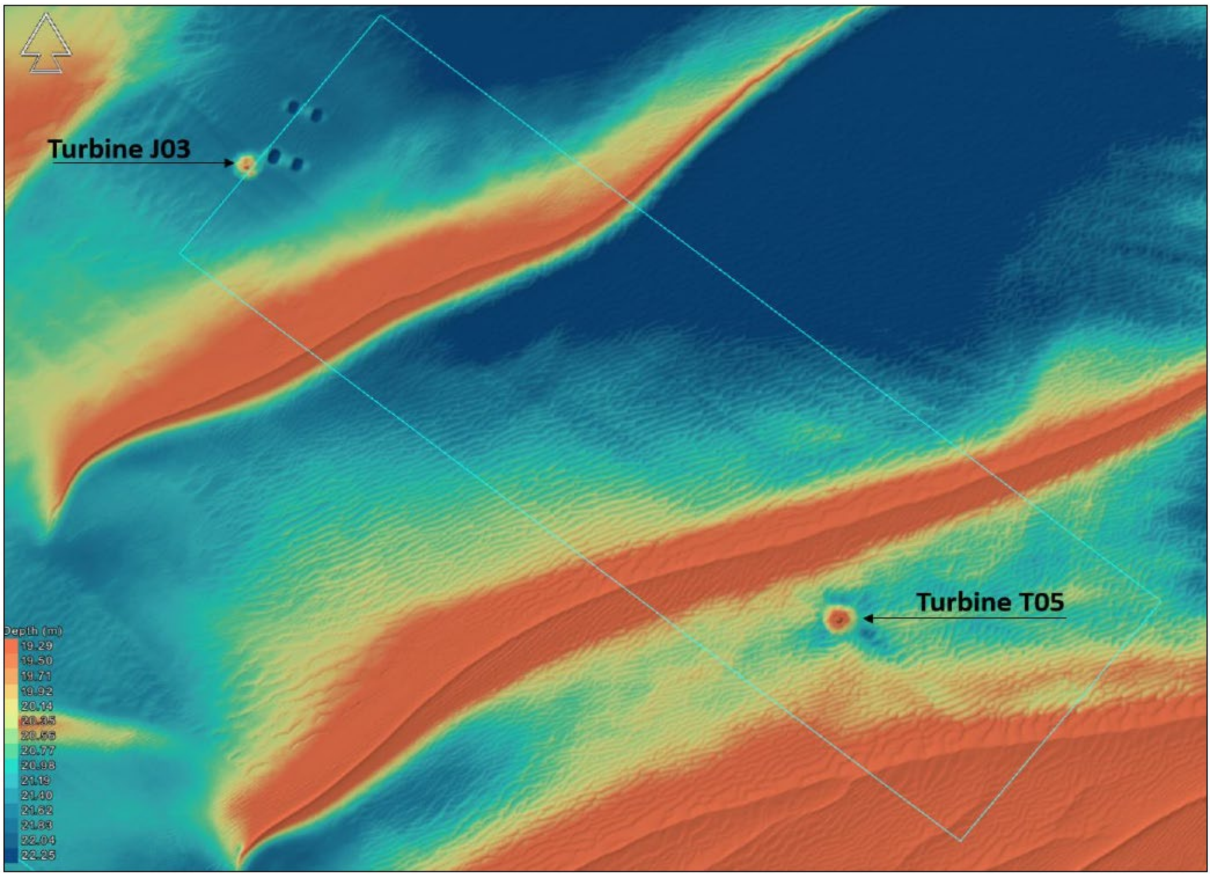

Figure 27 2018 bathymetry of Site 45

65. Since 2007, the northern sandwave has migrated south and the southern sandwave has migrated north (**Figure 28**). Between 2007 and 2017, the northern sandwave (profile A) migrated south by approximately 16.6m (**Figure 29**). However, from 2017 to 2018 the migration was to the north by approximately 6.4m, as well as increasing in height by approximately 0.3m. The sandwave at the centre of the site (profile B) has also changed migratory direction between 2017 and 2018 whilst maintaining its height (**Figure 30**). Before 2017, the sandwave migrated approximately 13.1m to the south. However, between 2017 and 2018 the migration direction changed to the north, with movement of approximately 6.5m.

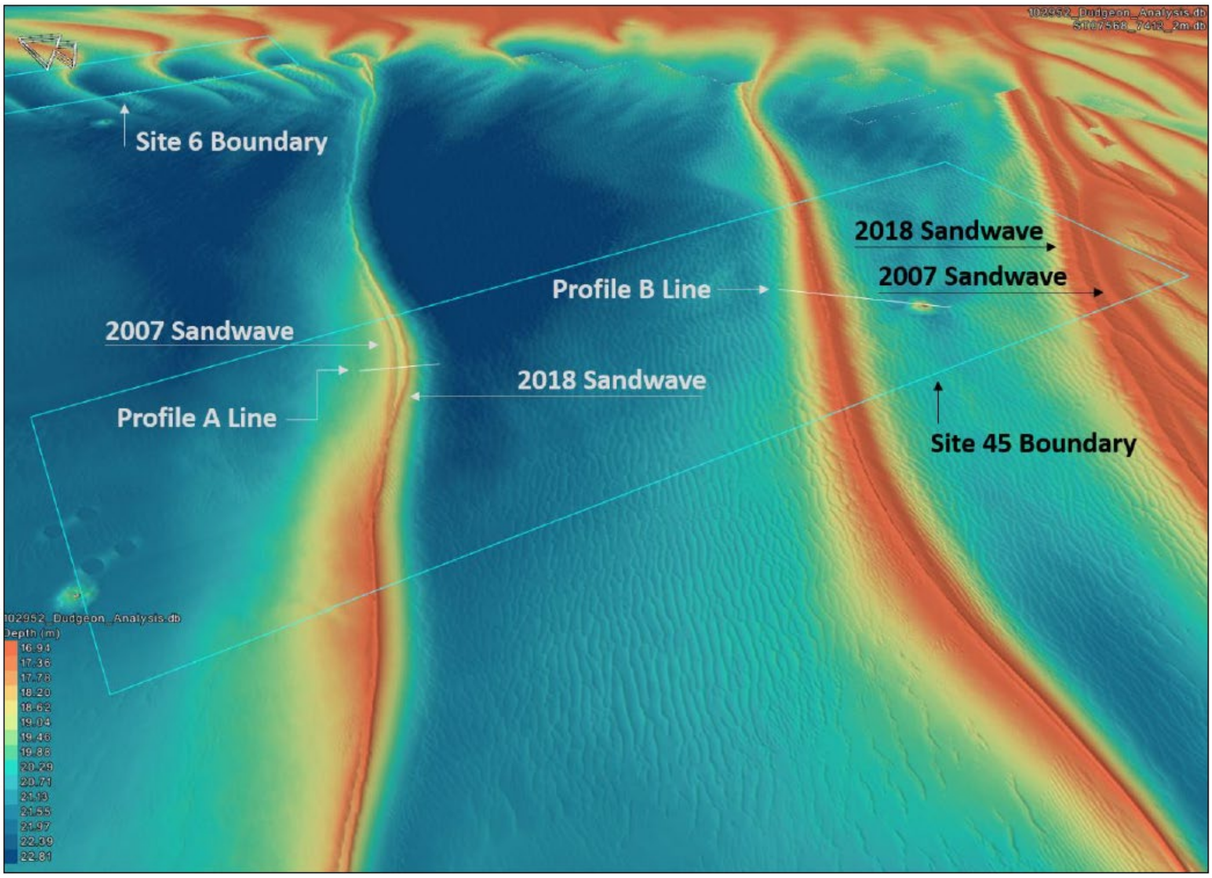

Figure 28 2018 data overlaid on the 2007 data for Site 45.

66. Profiles across the sandwaves are shown in Figure 29 and Figure 30

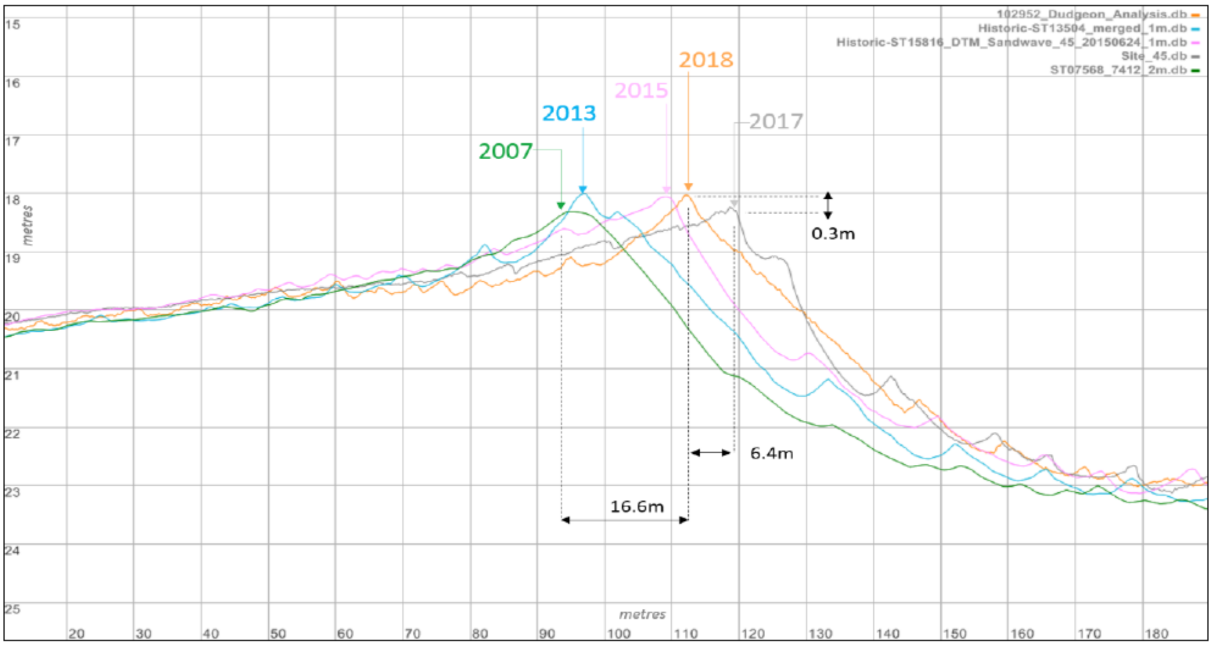

Figure 29 Site 45 seabed profile A demonstrating sandwave migration over eleven years

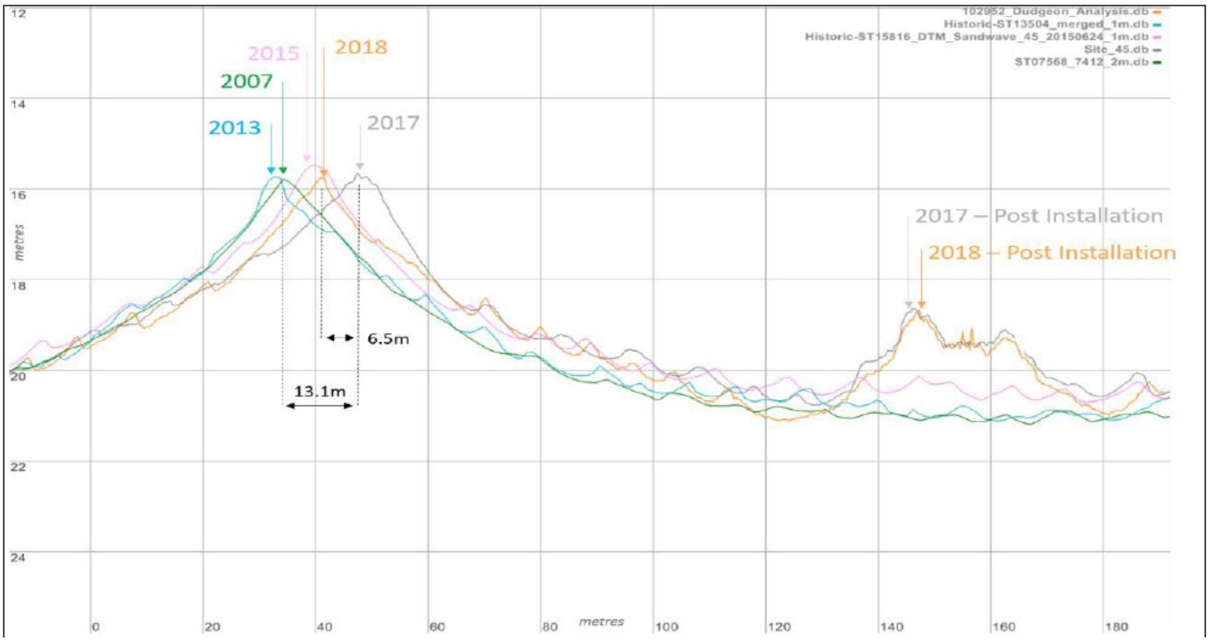

Figure 30 Site 45 seabed profile B demonstrating sandwave migration over eleven years

2.5.3.6 Sandwave Monitoring Site 78

67. Site 78 is in the centre of the east side of the DOW array area (**Figure 13**). The sandwave crest heights are approximately 3-4m with wavelengths of approximately 175-225m (**Figure 31**).

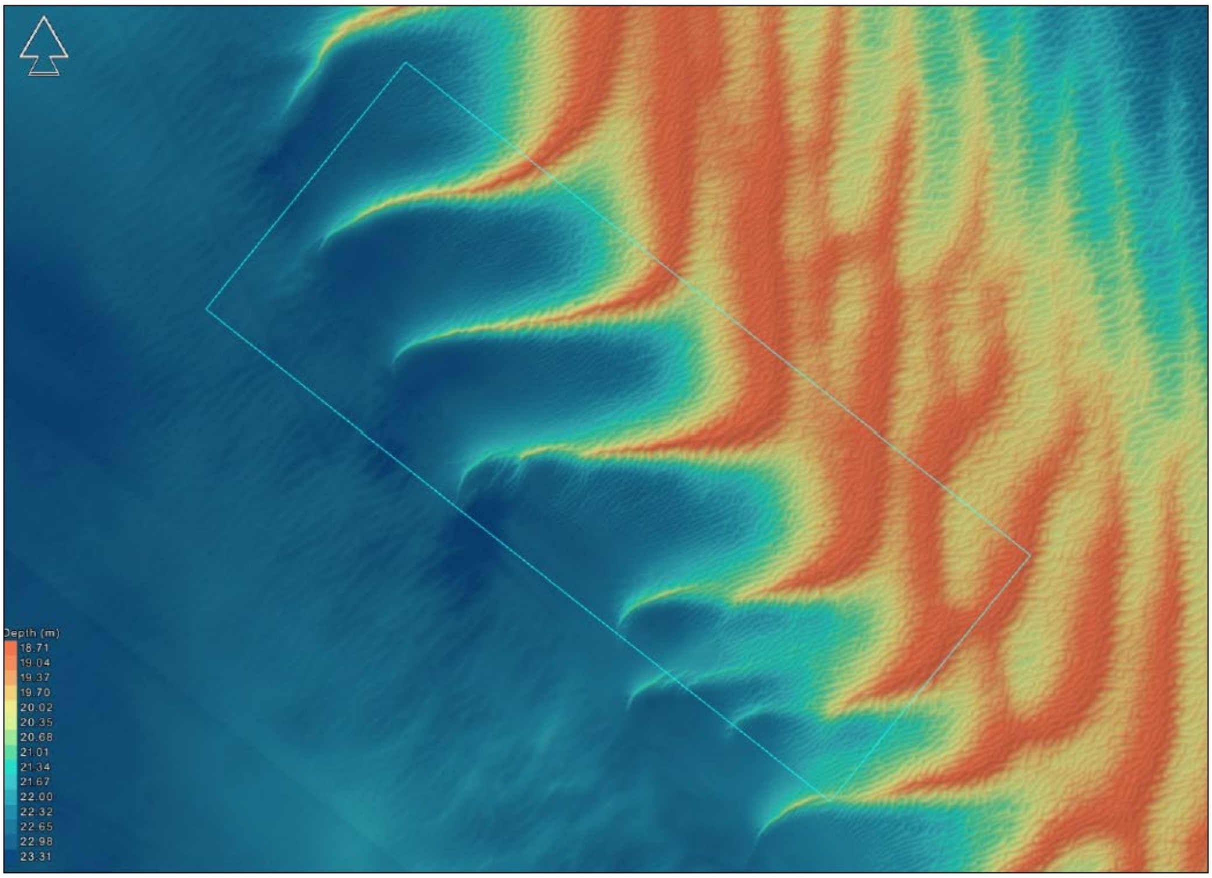

Figure 31 2018 bathymetry of Site 78

68. From 2007 to 2018 the general trend of sandwave migration was to the east and south. However, between 2017 and 2018 the migration direction was to the northwest (**Figure 32**). A profile across a sandwave shows that it migrated 16.6m to the south between 2007 and 2017, and 5.8m to the north between 2017 and 2018 (**Figure 33**). There is a minimal height change of the sandwave between 2017 and 2018 and this appears consistent across other sandwaves in the field.

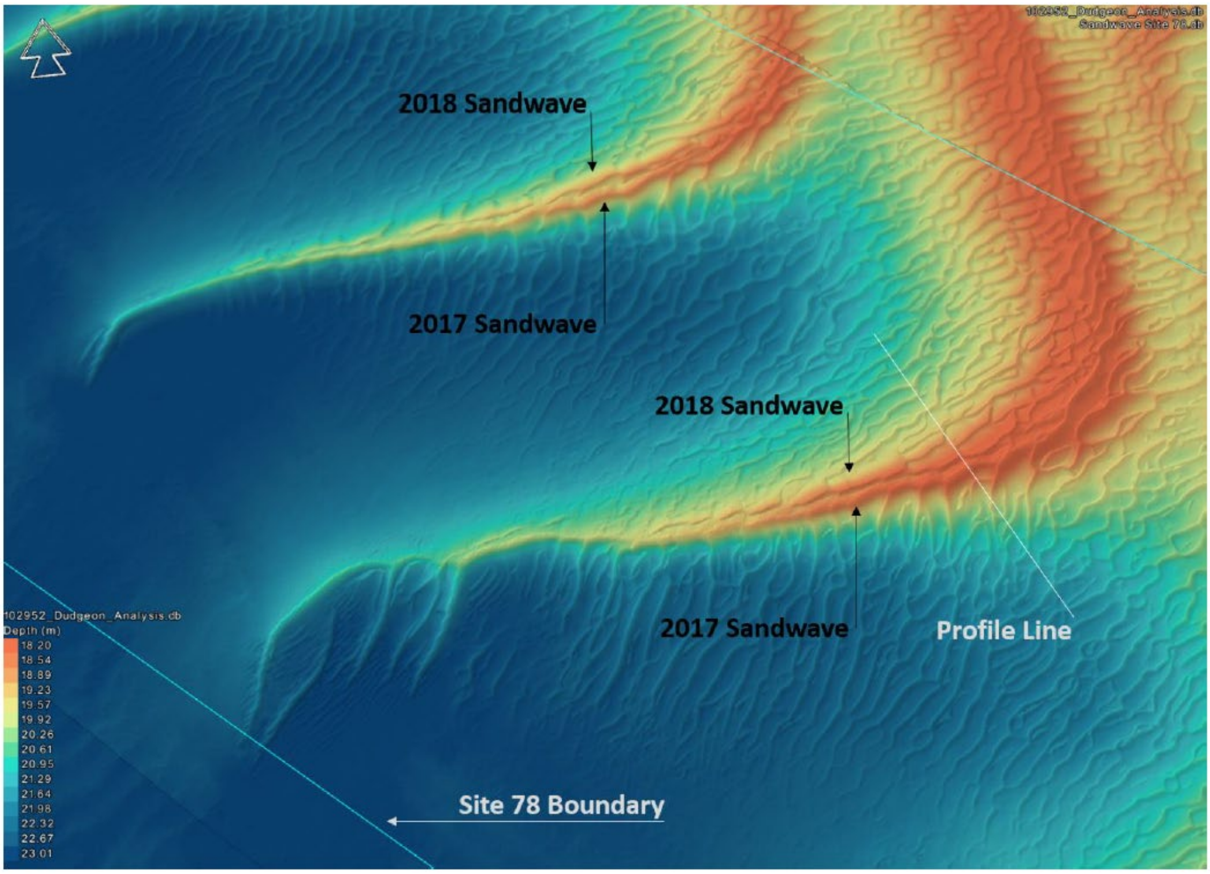

Figure 32 2018 data overlaid on the 2007 data for Site 78.

69. The profile across one of the sandwaves is shown in Figure 33

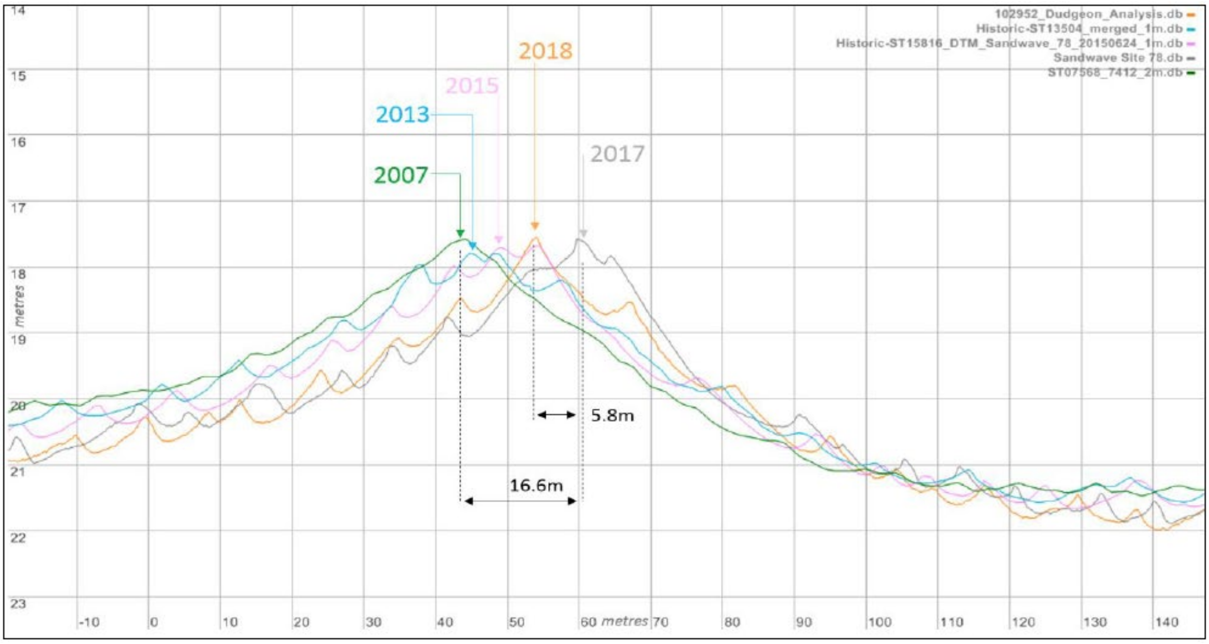

Figure 33 Site 78 seabed profile demonstrating sandwave migration over eleven years

2.5.3.7 Analysis of additional datasets

70. Interrogation of a longer time series of bathymetry data would be a useful exercise to define further changes in sandwave geometry and migration. However, with respect to DOW (and SEP/DEP), older bathymetric survey data that is not bespoke to the DOW site would have a much lower resolution and a lower accuracy and precision than the data collected post 2007, because it was collected on a regional North Sea-wide basis.

71. The data pre-2007 is EMODnet bathymetry, which is a freely available DEM product that provides information on the elevation of the seabed in European waters. The DEM is interpolated from various data sources, including bathymetric survey data, digital terrain model data, satellite derived bathymetry data, and GEBCO 2014 gridded data. Given the EMODnet bathymetry is a compilation of various data sources, the accuracy and precision of the data will vary depending on location. It is possible to qualitatively assess this (but not quantitatively) as each grid point in the DEM includes information on the number of values used for the interpolation and the range of water depths represented by that grid (including the standard deviation).

72. The most recent version of EMODnet bathymetry (v2020) has a grid size of 116m by 70m and any seabed features smaller than this would be difficult to identify, and it would not be possible to identify a crest location with any confidence. Sandwave crest height differences would also be difficult to compare, as there will be an artefact of the averaging effect inherent to the EMODnet grid (if a single grid square includes a crest and a trough, the average height would be the midpoint of that feature).

73. Overall, the analysis of low-resolution bathymetry data older than 2007 would add no value to the analysis and would be disproportionate to the additional information that could be derived. The bespoke data from 2007 to 2018 provides enough detail and sufficient length of sandwave evolution to determine if the turbine foundations are influencing the functioning of the sandwaves (and associated ripples).

3 Conclusions

74. Further detail in relation to the baseline characterisations of bedforms and updated figures showing MPAs and tidal ellipses have been provided. The baseline characterisation of the bedforms supports the conclusion that the sandwaves are mobile under natural conditions and would recover from any proposed levelling through re-establishment of sand transport pathways. The ellipses provide an indication of the maximum extent to which a sediment particle could travel in the water column. Most particles would not achieve this distance, because they would settle to the seabed closer to their release point (up to a kilometre along the axis of tidal flow) rather than travelling to the full extent of the ellipse.

75. Further detail on suspended sediment concentrations and interpretation of the SOW export cable plume dispersion modelling has been set out which shows that, if translated to SEP / DEP, the neap tide footprint is predicted to extend less than 3.6km, while the spring tide footprint is very small. Concentrations would be less

than 10mg/l. The predicted footprint of deposition would extend over a wide area but would be an undetectable thickness.

76. Finally, further consideration of pre- and post-construction changes to seabed bathymetry at DOW has been provided, with results indicating that, apart from areas of mobile sandwaves, there has been little change in the overall seabed depth across the site. As such, the sandwave migrations and heights can be considered indicative of naturally occurring processes across the DOW array area rather than being driven by changes caused by DOW. This supports the relevant assessment conclusions made by the Applicant with respect to SEP and DEP.

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