Project Restoration & Enhancement – Gemini Positioning Survey (PRE-GPS)

Analysis of MBES data, ROV imagery and morphological modelling for determining seabed dynamics in Gemini offshore windfarm in search for possibilities for large-scale oyster restoration

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Nederlandse samenvatting

Er is een grootschalig (oester)herstelproject gepland in het Gemini Offshore Windpark. Deze studie vormt de basis voor een dergelijk grootschalig natuurversterkend en opschalingsproject in dit gebied. Hiertoe werd een locatieonderzoek uitgevoerd, bestaande uit een bureauonderzoek en een veldsurvey. Dit rapport beschrijft de resultaten van beide onderdelen.

In deze studie zijn zeebodemkaarten van multibeam surveys en eerdere numerieke modelresultaten geanalyseerd en gecombineerd met een nieuwe dataset verkregen via een ROV-survey en monsters van de zeebodem.

Hieruit kan worden geconcludeerd dat de zeebodemdynamiek beperkt is tot relatief kleinschalige bodemvormen. Er zijn geen indicaties gevonden voor grootschalige of lokale sterke sedimentatie of erosie van de zeebodem.

In het relatief ondiepe gebied van de W5 Buitengaats OWF-turbine zijn kleinschalige bodemribbels zichtbaar, terwijl de zeebodem in het relatief diepe gebied van de B6 ZeeEnergie OWF-turbine meer pokdalig is, wat suggereert dat benthos de zeebodem voornamelijk vormgeeft.

Uit laboratoriumanalyses van 4 sedimentmonsters blijkt dat de mediane (D50) zandkorrelgrootte varieert tussen 191 en 289 µm, met grotere korrelgroottes in de staart van de verdeling (D90) die variëren tussen circa 394 µm en 613 µm. Opvallend is dat 3 van de 4 locaties een zeer zanderige zeebodem vertonen (met slechts 1-2% modder < 63 µm), terwijl ten westen van de K8-turbine in de ZeeEnergie OWF de zeebodem aanzienlijk anders is, met een slibpercentage van 42%.

Met de gegenereerde veldgegevens en analyse uit de voorliggende studie is de eerste stap gezet voor een verfijnde locatiekeuze voor natuurversterkende projecten in het Gemini-gebied.

Executive summary

A large-scale (oyster)restoration project is envisioned to be executed in the Gemini Offshore WindFarm (OWF). This study provides a basis for locating such a large-scale nature-enhancing and upscaling project in this area. To this end, a location survey was conducted, comprising a desk study and a field survey campaign. This report documents the results of this study.

High-resolution seabed maps from MBES and previous numerical modelling results were analysed, along with the generation of a new data set acquired from a ROV survey as well as seabed samples.

From these, it can be concluded that the seabed dynamics in the study area are limited to relatively small-scale bedform dynamics. There is no evidence for large-scale or local scale strong seabed sedimentation or erosion.

At the relatively shallow W5 Buitengaats OWF turbine area, the presence of small-scale ripples can be observed, whereas at the relatively deep B6 ZeeEnergie OWF turbine area, the seabed is more pock-marked suggesting the predominance of benthos shaping the seabed surface.

From laboratory analysis on 4 sediment samples, it follows that median (D50) sand sizes vary between 191 and 289 μm, with coarser grain sizes in the tail of the distribution (D90) varying between approx. 394 μm and 613 μm. Interestingly, 3/4 locations show a very sandy seabed (with only 1-2 % mud < 63 μm), whereas west of the K8 turbine in the ZeeEnergie OWF, the seabed was observed to be vastly different, having a mud percentage of 42% mud.

This study entailed the first steps towards a refined location selection of nature-enhancing projects in that it delivers on the general scarcity of field data related to high-resolution seabed morphology and sediment composition of the Gemini area.

1 Introduction

1.1 Background

A large-scale (oyster)restoration project is envisioned to be executed in the Gemini Offshore WindFarm (OWF). Recently, several studies have been conducted in this OWF of which the lessons learned can be benefitted from in next applications[1].

This study provides a basis for a large-scale nature-enhancing and upscaling project in the Gemini OWF by executing a location survey comprising a desk study, a field survey campaign with Lobster Robotics to capture an appreciable seabed coverage with high-resolution. In this report we document the results of both parts.

In a related report, we address the applicability of a computational tool for assessing the stability of ecological measurement frames and artificial reefs in offshore windfarms (NoRegret study 'SUBFRAME').

1.2 Goals

This Nature Regeneration North Sea study has the goal to select a location for the execution of nature-enhancing projects in the Gemini OWF based on the analysis of available data and a field survey. Specifically, the following goals are addressed:

- Generic guidelines (do's and don'ts) as well as a step-by-step approach for the location selection of nature-enhancing projects in offshore windfarms (Gemini OWF, this report);
- A GIS map of 3 locations of the Gemini OWF, including 1 on the WINOR location (**W**indfarm **I**nitiated **N**ature development with native **O**yster **R**eefs).

The overarching goal is to contribute with this project to practical knowledge gain for location selection for nature-enhancing measurements in an offshore windfarm.

1.3 Approach

De following tasks have been performed:

- Collection of available bathymetric data of the area of the Gemini windfarm to assess yearly displacement of seabed features (megaripples) and to identify knowledge gaps.
- Collection of sediment data of the area of the Gemini windfarm where possible and to identify knowledge gaps.
- Location selection for nature-enhancing measurements in the Gemini windfarm based on an analysis of the above-mentioned data. Criteria for the assessment of this preferred location are seabed morphology, seabed substrate, dynamics of bedforms, currents and wave action near the bottom, water depth, layout of wind turbines and windfarms, possible wishes of Gemini, etc.
- Conduction of field survey (T0/exploratory survey) on the suggested locations including the WINOR location with Lobster Robotics for high-resolution seabed mapping (imagery) and to assess whether this location is suitable for a large-scale nature-enhancing project.
- Delft3D workshop at Deltares for project partners.

The remainder of this document addresses the above-mentioned aspects.

[1] See e.g. https://www.therichnorthsea.com/project/gemini/

2 PRE-GPS: Analysis

2.1 Morphology

The seabed in the Gemini OWF is characterized based on various bathymetric multibeam surveys (MBES) that have been conducted over the past years.

The mapping with largest spatial coverage stems from the survey in 2011, well before the 150 wind turbines were installed between February 2016 and August 2016. The spatial map of the seabed according to the MBES 2011 survey is shown in Figure 1, including the location of the offshore high-voltage stations (OHVS), the location of the WINOR study location in the westerly-located ZeeEnergie windfarm; refer to the annotations. Also, 6 locations in the ZeeEnergie windfarm are detailed in Figure 2 (1A and 1B) Figure 3 (2A and 2B) and Figure 4 (3A and 3B), respectively.

From these figures, the following can be observed:

- a generally deeper seabed level in the NW part of ZeeEnergie (< LAT-35 m) against a generally more shallow seabed level in the SE part of Buitengaats (> LAT-29 m). Ddepth differences amount to max. more than 6 m (Figure 1);
- relatively irregular large-scale morphological patterns in particularly Buitengaats indicating the underlying glacigenic origin (Figure 1). In case of limited sand coverage, the possible presence of hard substrate near or at the seabed surface is relevant for ecological developments such as the potential for oyster riff recovery.
- The presence of irregular bedforms with a length scale of order 50-m (Figure 2);
- The presence of megaripple fields in the MBES surveys from 2020 (polygon 2A) and 2017 (polygon 2B); refer to Figure 3;
- The presence of edge scour adjacent to the scour protection around the monopiles (monopile diameter is 7 m); see Figure 4.

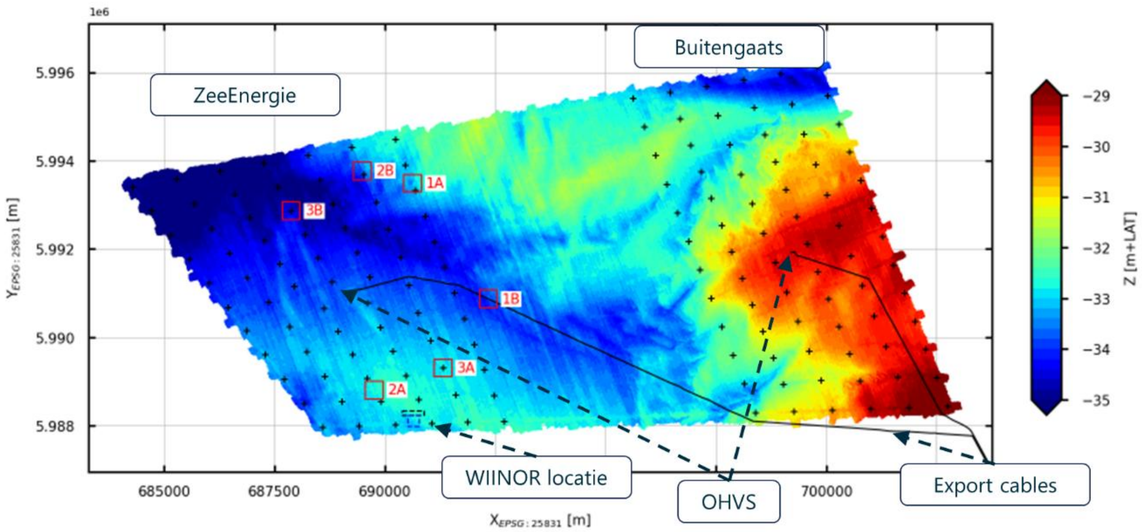


Figure 1 Bathymetry map based on MBES 2011.

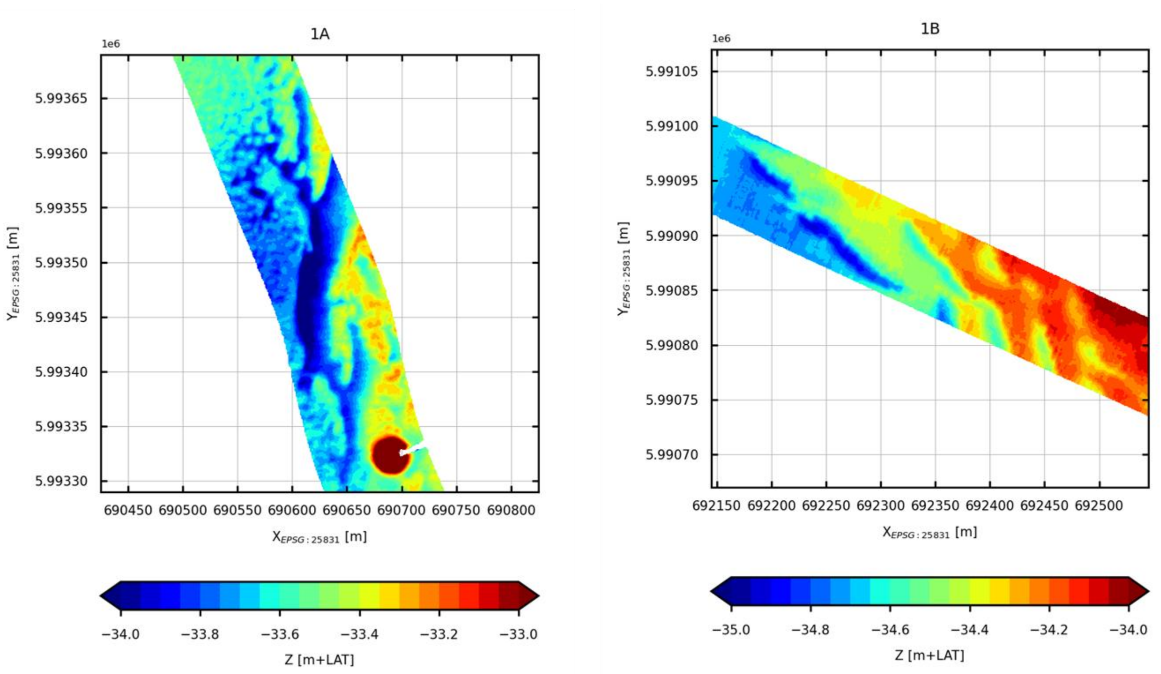


Figure 2 Detailed view of large-scale seabed features around polygon 1A (left) and polygon 1B (right). Both data sets correspond to seabed surveys from 2017.

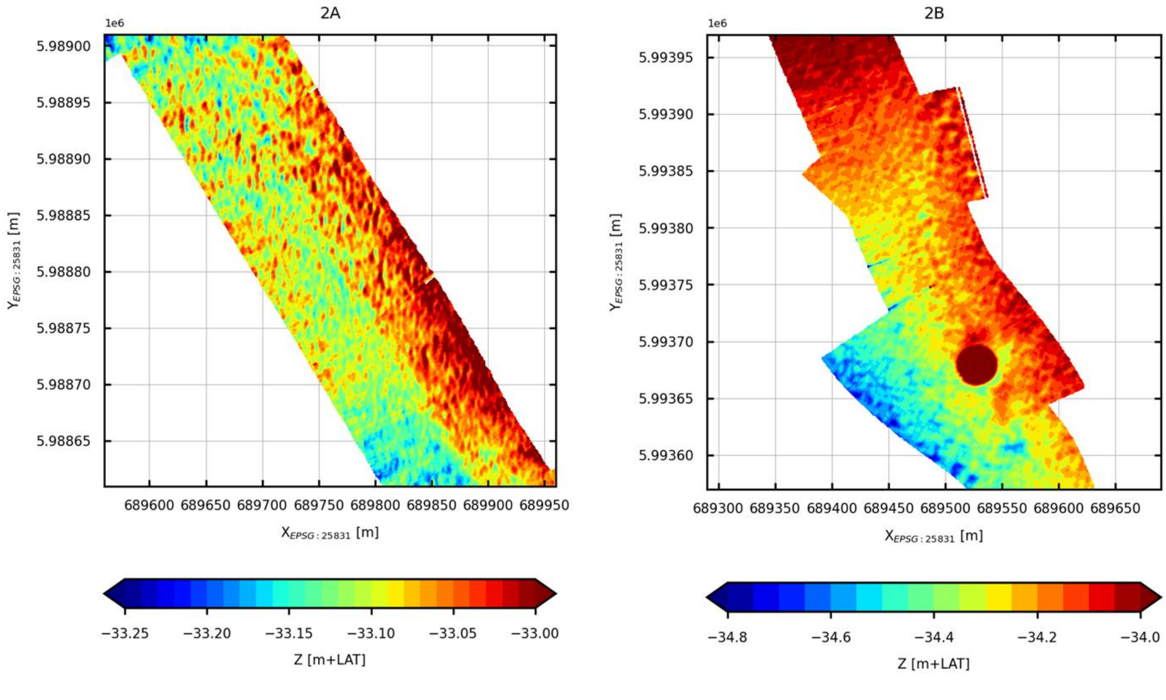


Figure 3 Detailed view of small-scale seabed features (megaripples) around polygon 2A (left) and polygon 2B (right). Data sets correspond to seabed surveys from 2020 (2A) and 2017 (2B).

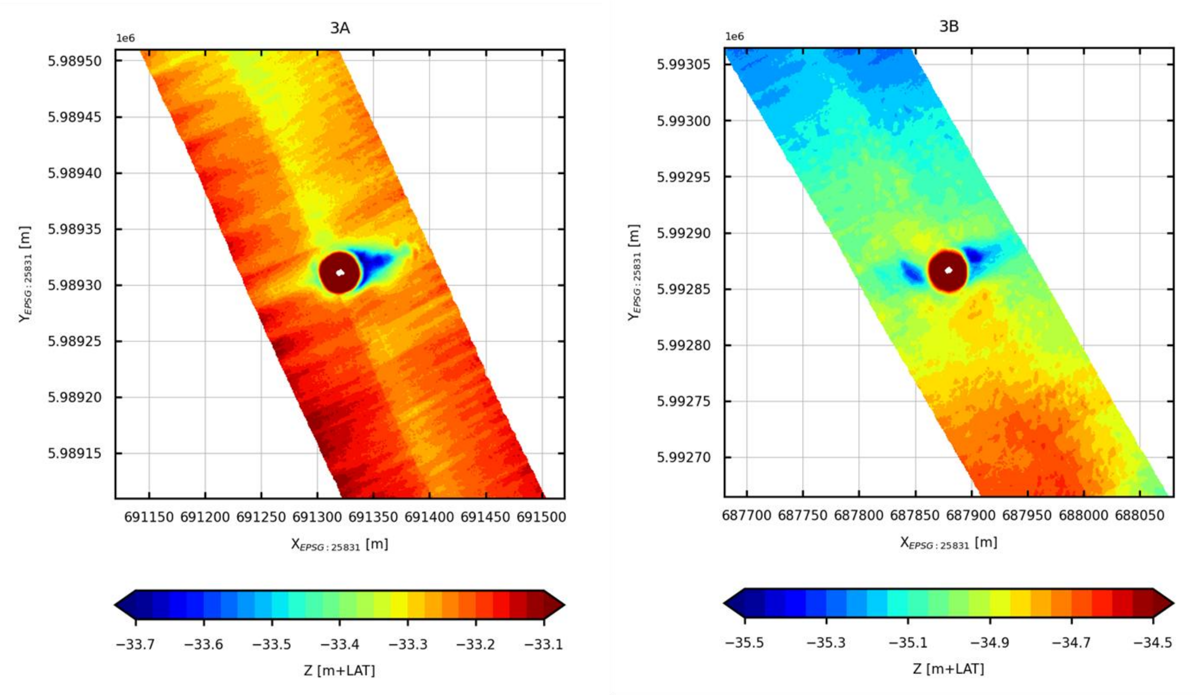


Figure 4 Detailed view of seabed features around monopiles (polygon 3A; left and polygon 3B; right). Both data sets correspond to seabed surveys from 2020.

2.2 Morphodynamics based on MBES surveys

By tracking the seabed surface through time, the seabed morphodynamics can be investigated which is relevant for nature-enhancing measures such as the identification of areas that undergo sedimentation or erosion, as well as the degree of either process..

Table 1 shows an overview of available bathymetric surveys in the study area. The survey year, the resolution and the spatial coverage are listed. From the table it follows that after 2011 no surveys with full spatial coverage have been conducted, however, a few high-resolution surveys are available around the in-field cables (for example, see Figure 5) that are useful for determining the local dynamics of the seabed (Figure 6 and Figure 7).

Table 1 Available MBES surveys at the Gemini OWF

Year	**Resolution**	Coverage
2007	25 m	Full (excl. NW)
2011	2 m	Full
2014/2015	0,5 m	Infield
2017, okt	0,5 m	Infield
2018, dec	1 m	Infield
2020, apr	0,5 m	Infield
2025	0,5 m	Export

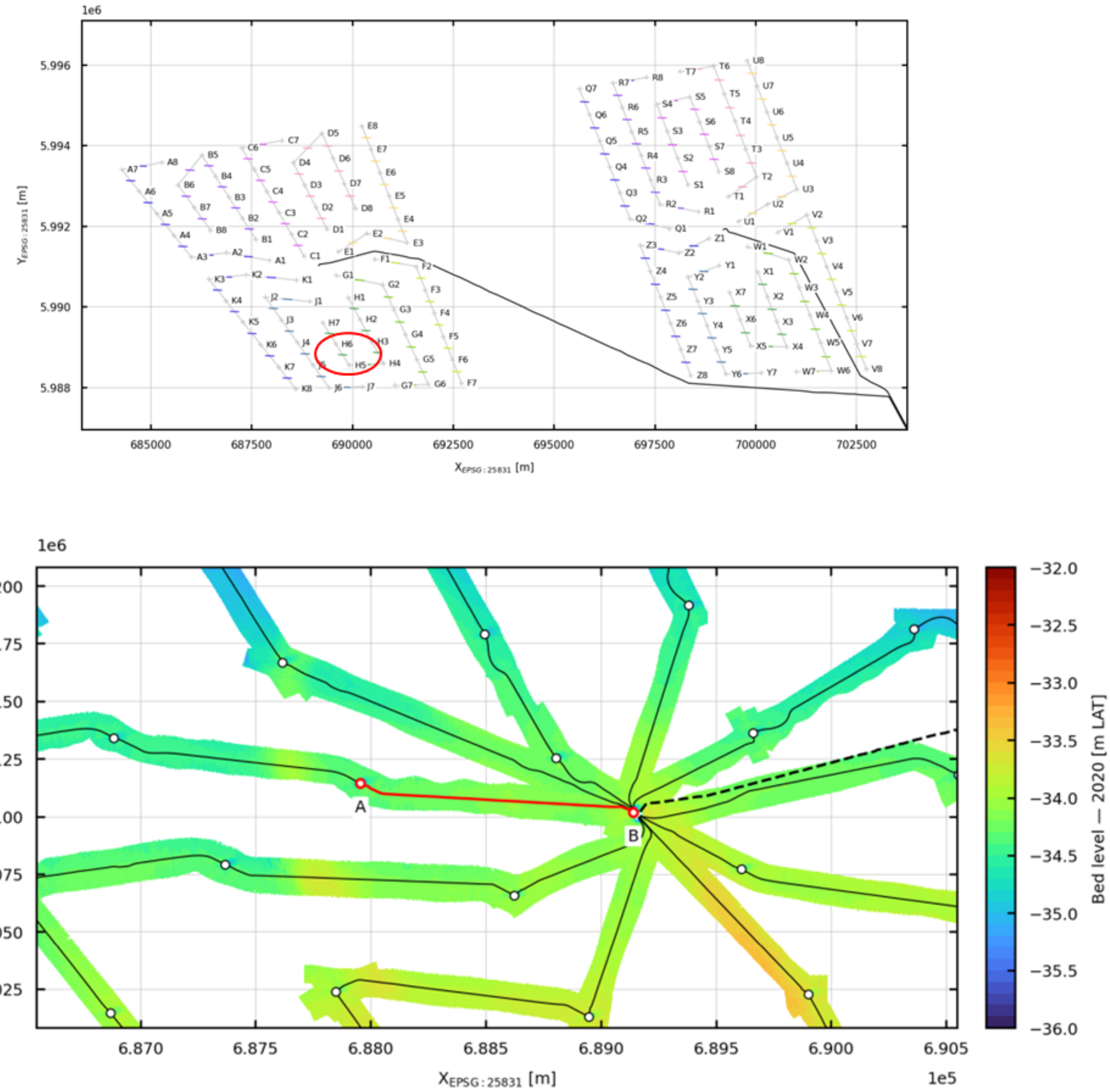


Figure 5 Bathymetry map around part of in-field cables in ZeeEnergie OWF. The red ellipse in the upper panel indicates the location of the transect along which the seabed level is shown in Figure 6. Idem for the red line in the lower panel (A-B) for which the corresponding seabed level developments are shown in Figure 7.

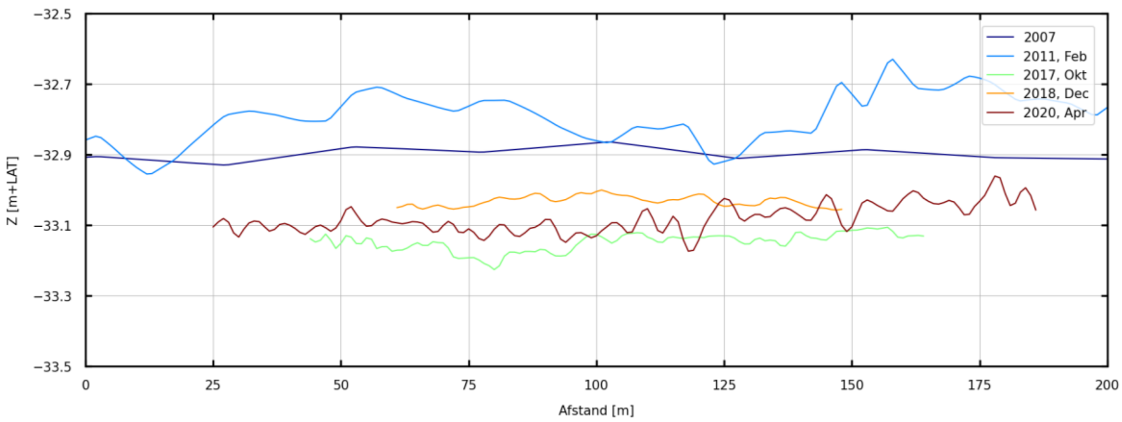


Figure 6 Dynamics of the seabed along a section of the in-field cable in the ZeeEnergie OWF (see Figure 5 for location of this transect).

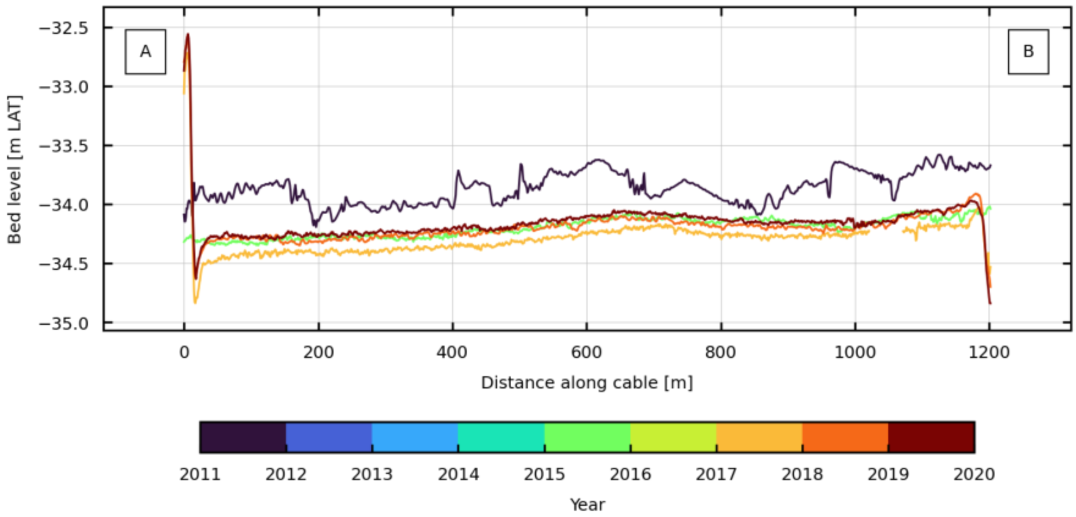


Figure 7 Dynamics of the seabed along a section of the in-field cable in the ZeeEnergie OWF (see Figure 5 for location of this transect).

From Figure 6 and Figure 7, it follows that generally, the seabed has been relatively stable in the period between 2007 and 2025. Maximum differences in seabed level between the various surveys amount to about 50 cm. Specifically, if a trend exists, the trend from 2011 onwards tends to be erosional rather than depositional. It could be that in practice, these differences are smaller, additionally, the observed difference between Figure 6 and Figure 7 between 2011 and later years could be resulting from different definitions of ordnance datum (LAT2006 versus LAT2018 reference planes) which are used in the mapping of the seabed throughout these years. Differences between 2007 and 2011 are likely the result from differences in resolution of both surveys (Table 1). Remaining local differences are related to the dynamics of (mega)ripples which in the surveys considered herein, have an amplitude of max. 10-20 cm.

The seabed morphodynamics is mainly related to dynamic bedforms; from the 2011 survey, it follows that ripples have a wave height H = 0.2-0.4 m, wave length L = ca. 20-30 m, migration rate γ = ca. 5-10 m/jr (in easterly directions, in the dominant flood direction).

2.3 Morphodynamics inferred from ROV imagery

The seabed morphodynamics can also be interpreted from video imagery taken by the ROV 'Bluestream' at the WINOR study site (see Figure 1 for location) on two dates. It concerns an ROV survey on 21-May-2024 and 20-Oct-2024. These surveys were conducted to assess whether 4 oyster spat collector frames for the WINOR study (Figure 8) could be localized. ROV imagery ('stills' from the video recording) for frame #1, #2, #3 and #4 on either or both occasions are shown in Figure 9, Figure 10, Figure 11 and Figure 12, respectively. The steel arm with the lifting eye has a height of about 50 cm. From the figures it follows that:

- Frame #1 at both 21-05-2024 and 20-10-2024 is clearly present on the ROV images and did not undergo (net) sedimentation (Figure 9 and Figure 10).
- Frame #2 is clearly visible on the ROV image (with marine growth), but upside down (Figure 11, left), possibly due to turning during frame operations. No evidence exists for sedimentation.
- Frame #3 is clearly present on the ROV image, however upside down (Figure 11, right) possibly due to turning during frame operations. No evidence exists for sedimentation.

- Frame #4 is clearly present on the ROV image, albeit only the steel arm and lifting eye on top. Seabed material is visible on 21-05-2024 which contains shells (possibly oysters) and shell fragments. It is possible that the location underwent some local sedimentation, up to about 10-20 cm.

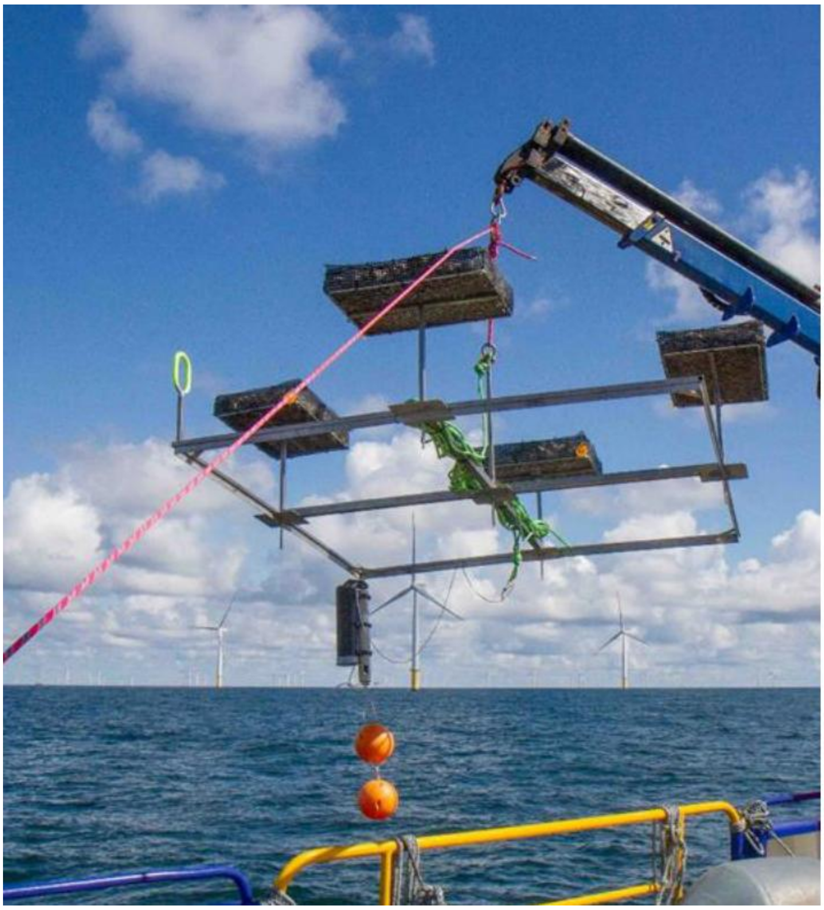
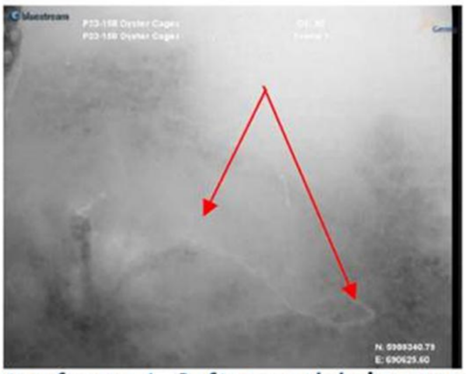


Figure 8 WINOR oyster spat collector frame.



Oyster frame 1. Soft rope debris wrapped aropund multiple points of the frame.

Oyster frame 1, centre of the frame lifting ey

Figure 9 ROV imagery of Frame #1 on 21-05-2024.

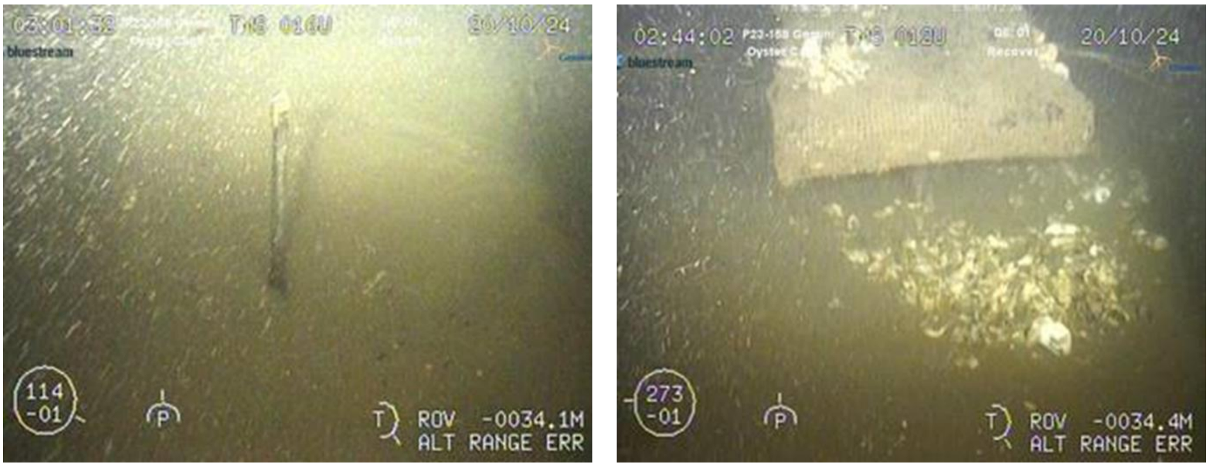


Figure 10 ROV imagery of Frame #1 on 20-10-2024.

Figure 11 ROV imagery of Frame #2 on 21-05-2024 (left) and Frame #3 on 20-10-2024 (right).

Figure 12 ROV image of Frame #4 on 21-05-2024.

2.4 Morphodynamics based on morphological modelling

WaterProof has executed simulations with a numerical Delft3D model to gain insight into the order of magnitude sediment transport and sedimentation/erosion that can be expected during storms when large waves are present in the area (refer to Figure 13). These are exploratory simulations, since as yet, no measurements data are available on (combined) currents, sediment concentrations, sediment transport and sediment composition of the seabed as well as on observations from erosion or sedimentation of the seabed to calibrate the model.

Figure 14 shows an example of the results of a model run; in the left panels, the computed bed-load transport of sediment is shown (upper panel) as well as the suspended transport in the water column (lower panel) during the storm of 24-November 2023. From the figure, it follows that suspended transport is dominant. In the right panels, the spatial gradients (differences) of both transport modes are shown. From these, the seabed response can be inferred, theoretically; the blue-colored patches denote the areas where erosion is expected, whereas the red-colored patches denote the areas where sedimentation is expected.

From the panels it follows that the general tendency is a rather stable morphology or slightly erosive. This means that in practice, no large seabed level changes are expected. More specifically, large-scale sedimentation in the Gemini OWF is expected to be very limited. This is consistent with the observed limited morphological changes in the time series of the MBES surveys (refer to §2.2).

It should be noted that the above conclusion based on gradients that are evaluated from the total transport (bed-load + suspended load). It is acknowledged however, that phase lag effects may be present which complicate straightforward conclusions on morphodynamics. Also, the simulations relate to storm conditions, while acknowledging that year-round conditions may also contribute to morphological changes over the longer-term.

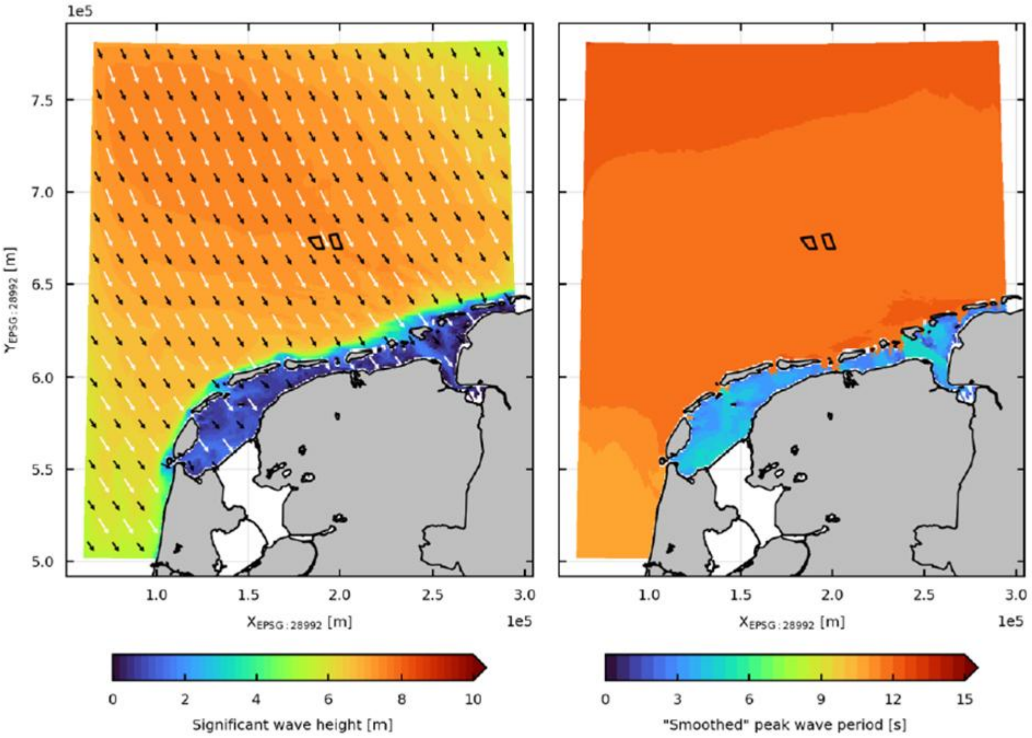


Figure 13 Computed waves with the SWAN model during a storm on the North Sea in November 2023; significant wave height (left) and peak wave period (right). The Gemini OWF, 85 km off the coast is indicated by the 2 black polygons (ZeeEnergie en Buitengaats).

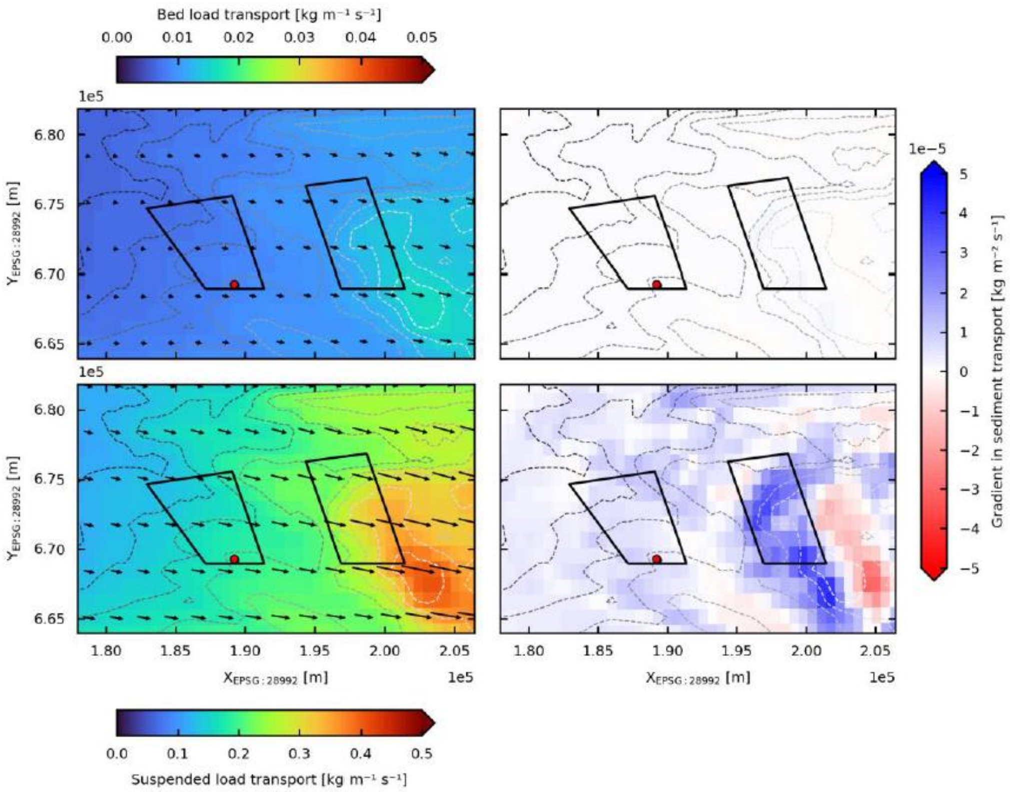


Figure 14 Computed sediment transport, subdivided into bed-load transport (upper left) and suspended transport (lower left) and spatial gradients (differences) in the sediment transport (upper right and lower right) as a measure for the changes in bed level by sedimentation or erosion.

2.5 Conclusions on seabed morphodynamics

From the analyses on MBES survey data, ROV imagery of the Bluestream in October 2024 as well as morphological model computations it is concluded that:

- Generally, only relatively limited morphodynamics occur in the Gemini OWF; maximum bathymetric differences are about 0.5 m between the surveys in the period 2007-2020, including uncertainties related to different properties of the underlying measurements data such as resolution and ordnance datum.
- The seabed morphodynamics is mainly related to dynamic bedforms; from the space-covering MBES 2011 survey, ripples are identified with a wave height H = 0.2-0.4 m, wave length L = ca. 20-30 m, migration rate γ = ca. 5-10 m/jr (in easterly directions, in the dominant flood direction);
- ROV imagery show that the seabed dynamics during the deployment period of the 4 oyster spat collector frames was relatively limited;
- Morphological model computations indicate a generally morphologically-stable situation with no tendency for large-scale sedimentation, at least not for the storm period around 24 November 2023, while noting that the model has not yet been calibrated with measurements data.

2.6 PRE-GPS location selection

The location selection for the execution of a ROV survey is based on the large-scale differences in bathymetry between ZeeEnergie-NW and Buitengaats E and possible underlying differences in morphogenesis. These differences in geological origin (Section 2.1) can be signalled through regional or local differences in composition of the seabed.

Accordingly, the 3 target locations for the ROV 'Scout' of Lobster Robotics, and after discussion with Gemini, were defined at:

- Area near turbine W5 – Buitengaats (shallow location)
- Area near turbine B6 – ZeeEnergie (deep location)
- Area near the WINOR site (southern part of ZeeEnergie)

Refer to Figure 15 for the location of these sites.

In view of the limited knowledge about the sediment composition of the seabed, as well as of the spatial differences thereof, at these 3 locations also local seabed sampling with a Van Veen grab sampler were foreseen. Refer to §2.8 for more information.

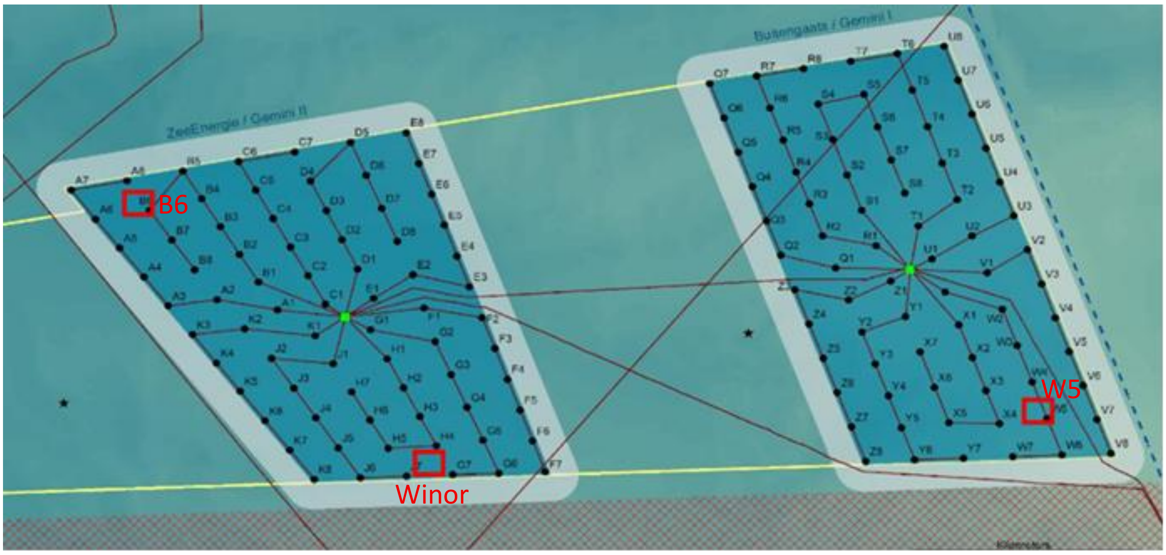


Figure 15 PRE-GPS location selection in Gemini offshore windfarm; see the red-colored rectangles.

2.7 ROV imagery seabed July 2025

On July 22nd, 2025, the seabed in the targeted areas around turbine B6 in the ZeeEnergie OWF and around turbine W5 in the Buitengaats OWF, refer to the red-colored rectangles in Figure 15, were successfully surveyed with the ROV 'Scout' from Lobster Robotics. Adverse weather conditions hindered the surveying of the WINOR location, so no data has been acquired from that site.

The high-resolution seabed maps produced from this survey are shown in Figure 16 and Figure 17 for the W5 Buitengaats OWF and B6 ZeeEnergie OWF locations, respectively. The following observations can be made from these maps:

- W5: The presence of a fine-scale wavy ripple field can be seen on top of a gently-sloping seabed with maximum bed level differences of approx. 10 cm (-30.53 to -30.43 m). The ripples have wavelengths of about 15 cm and wave heights of about 3-5 cm. At some locations, circular-shaped features of various sizes can be seen; these likely correspond to shells, most of them being open bivalves, as signalled through a topographic depression (blue) that directly neighbors a topographic high (red).
- B6: unlike the above-described map at W5, the map from this B6 area is quite different in bed morphology, being more pock-marked with ripples being only present in part, in the eastern corner of the map, if any. This may also be associated with differences in seabed sediment composition (see §2.8), suggesting that this site has higher mud percentages. The texture indicates a predominance of benthos shaping the seabed surface. Overall bed level differences are similar to that at W5 at this local scale (-36.37 to -36.26).

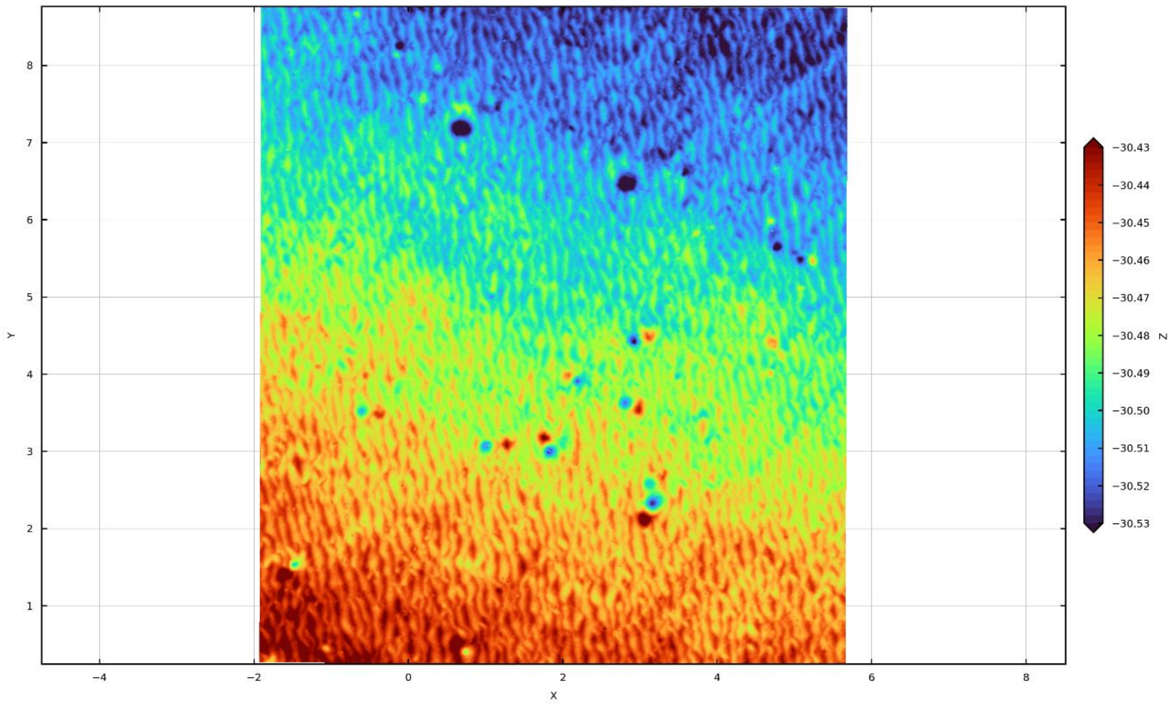


Figure 16 Bathymetry map at WTG-W5 West (Buitengaats OWF).

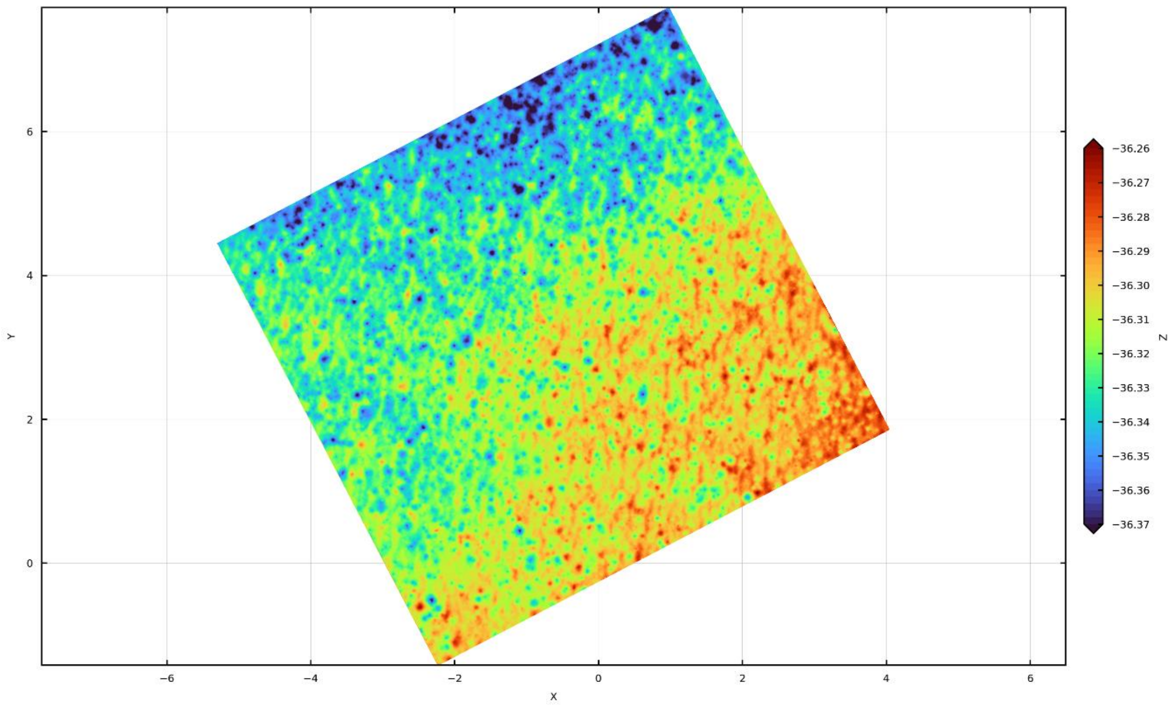


Figure 17 Bathymetry map at WTG-B6 East (ZeeEnergie OWF).

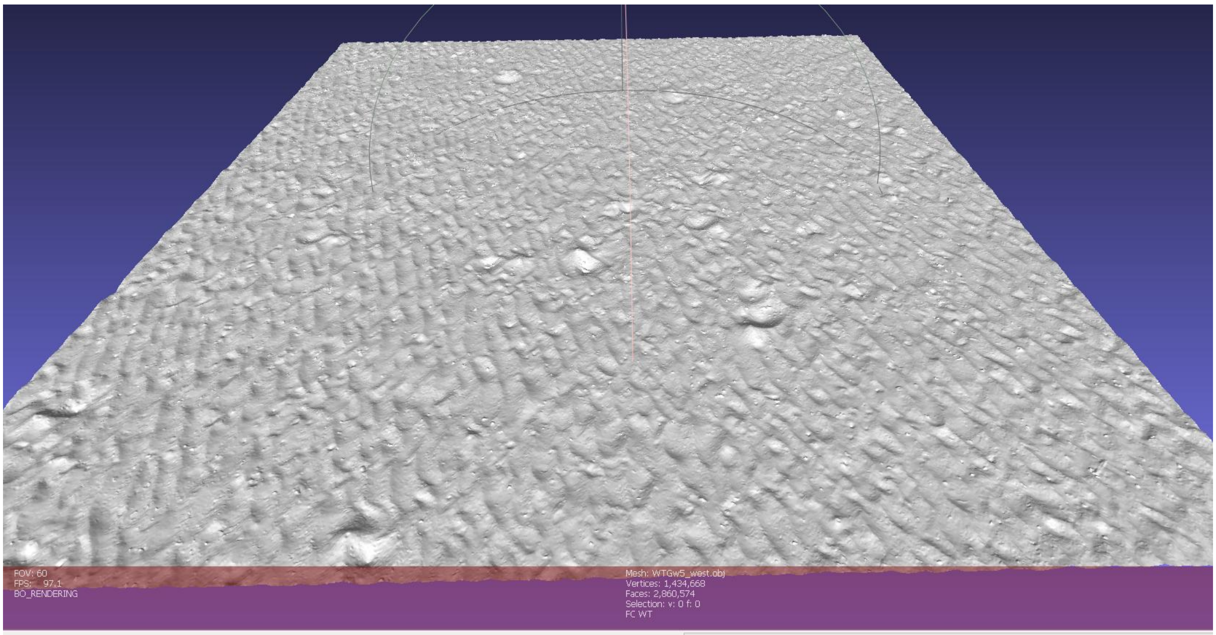


Figure 18: 3D-Bathymetry map at WTG-W5 West as made by Lobster Robotics

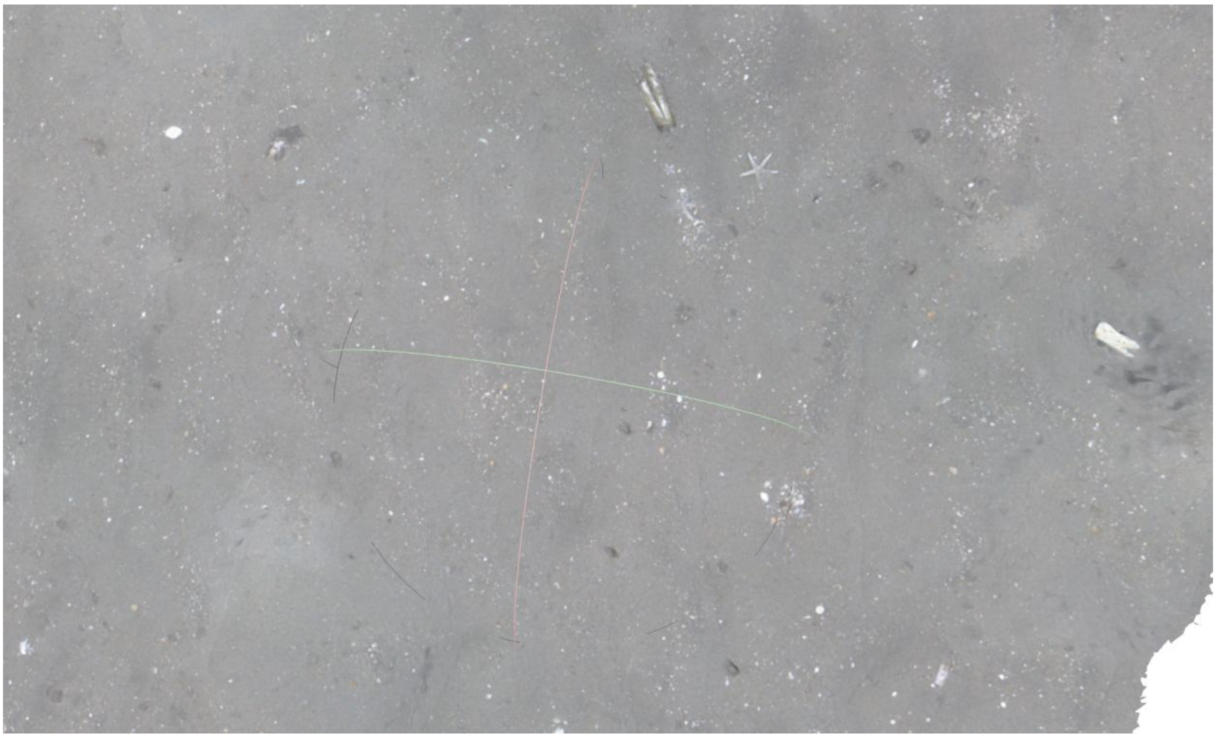


Figure 19: Top-down view of the seabed, clearly seastars and 'scheermessen' visible, at WTG-W5 West as made by Lobster Robotics

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Figure 20: Top-down view of the seabed at WTG-W5 East

2.8 Seabed sediment composition

During deployment at the 1st survey location of the field campaign on 22-July-2025, unfortunately, the Van Veen grab sampler got damaged so that data on the seabed composition could not be gathered.

However, during the execution of another field campaign around the Gemini OWF and after approval by Gemini and Rijkswaterstaat, WaterProof obtained seabed samples with a Van Veen grab sampler. These samples were taken at 4 different locations around the ZeeEnergie OWF on October 22nd, 2025; refer to Figure 21. The samples were taken in the following order (from East to West):

- at a seabed location east of the ZeeEnergie plot, denoted as '1-WO';
- at a seabed location approx. 150 m east of the SW turbine K8, denoted as '2-TO';
- a seabed location approx. 150 m west of the SW turbine K8, denoted as '3-TW';
- a seabed location west of the ZeeEnergie plot, denoted as '4-WW'.

After collection of the sediment samples, the samples were transported to the laboratory of WaterProof for the determination of the wet bulk density, dry bulk density, sand/mud content and the grain size distribution of the sand fraction. A photo impression of subsamples 1-WO and 3-TW that were used for the analyses, is shown in Figure 22. The measured bulk densities and sand/mud contents are presented in Table 2. Results on measured grain size distributions based on dry sieving are shown in Figure 23. From the table and figure, the following observations can be made:

- the seabed east and west of ZeeEnergie OWF are relatively similar in terms of wet bulk density (2003 and 2056 kg/m^3) and dry bulk density (1684 and 1741 kg/m^3).
- the seabed near the turbine K8 is less dense, particularly at 3-TW; this sample has a much lower bulk density (wet/dry bulk density = 1519/886 kg/m^3).
- the seabed is very sandy at 3/4 of the locations ($\geq$ 98% sand), thus hardly contains any fines (i.e. mud < 63 μm), however, at 3-TW, the sample comprised 42% fines. This suggests large differences in seabed composition over short distances (compare 3-TW with 2-TO which are spaced apart by only approx. 300 m). The reason for this is yet unknown. More seabed samples from the area are needed to confirm the locality of this fine layer: is it a local muddy

patch or is it more abundant? This is particularly relevant information for the purposes of large scale oyster rehabilitation as well as for sedimentological-ecological habitat mapping in general.

- The seabed sand is coarsest at the eastern location 1-WO with a median (D50) grain size = 289 µm and a 90-pct (D90) grain size = 476 µm.
- Sieve curves are rather similar for the 2-TO and 4-WW locations, while the latter location displays a somewhat wider range of grain sizes, seen through the lower value for D10, but higher value for D95.
- The median grain size of the sand fraction is lowest at 3-TW (D50 = 191 µm) which is consistent with the higher percentage of fines observed at this location (42%), however, the D95 of the sand fraction is still rather high (402 µm) and similar to that observed at 2-TO and 4-WW (394 and 447 µm, respectively). This may suggest the presence of a distinct (thin?) muddy layer covering the overall sandy shallow subsurface.

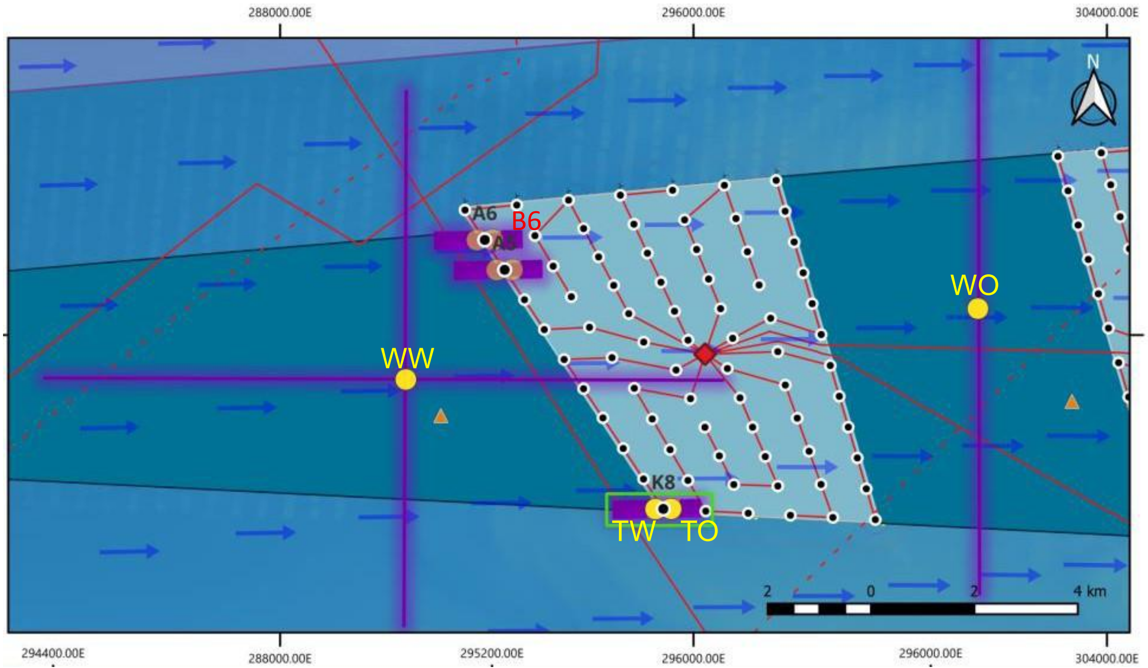

Figure 21 Locations of the 4 seabed samples. The B6 location is indicated. The W5 location is not indicated (located east, in Buitengaats OWF, here not shown).

Figure 22 Photographs of subsamples. Upper left: photo of subsample 1-WO. Note the presence of surface-sticking small spikes belonging to a benthos species. Diameter of the pot is about 4 cm, for scale. Upper right: photo after air drying a month later, from which the coarse sand grains and shell fragments can clearly be seen. Lower left: wet sieving of the very sandy 1-WO sample to separate sand/mud. Lower right: idem, for the muddy 3-TW subsample; note the fines in the drain.

Table 2 Measured sediment parameters

Sample ID	Wet bulk density (kg/m^3)	Dry bulk density (kg/m^3)	Mass fines < 63 µm (%)	Mass sand > 63 µm and < 2 mm (%)	Notes
PREGPS_1_WO	2056	1741	2	98	rich in shell fragments
PREGPS_2_TO	1905	1598	1	99	some shell fragments
PREGPS_3_TW	1519	886	42	58	hardly shell fragments
PREGPS_4_WW	2003	1684	2	98	some shell fragments

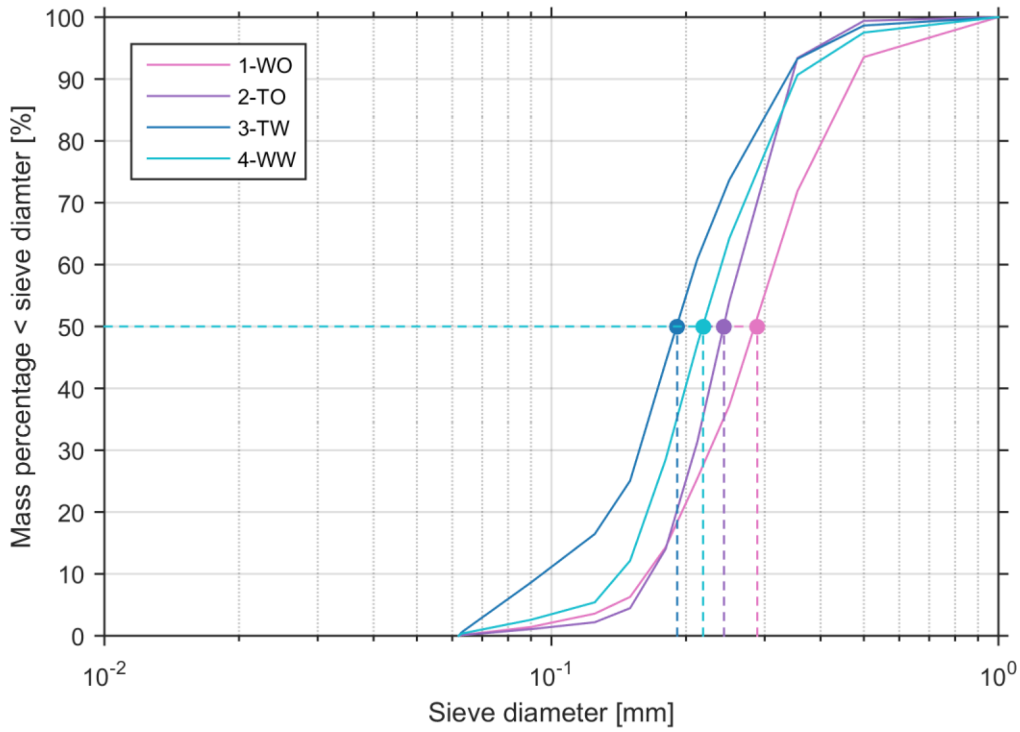

Figure 23 Sieve curves for the 4 seabed samples with Van Veen grab sampler as measured in the laboratory of WaterProof.

Table 3 Percentiles of grain size distribution of the sand fraction

Sample ID	D10 (μm)	D30 (μm)	D50 (μm)	D70 (μm)	D90 (μm)	D95 (μm)
PREGPS_1_WO	164	227	289	349	476	613
PREGPS_2_TO	167	210	243	293	346	394
PREGPS_3_TW	96	158	191	239	338	402
PREGPS_4_WW	142	183	218	273	352	447

3 Conclusions & Recommendations

The following conclusions can be drawn with respect to the seabed characteristics specifically at the Gemini site, pertaining to the location selection of nature-enhancing projects in this area:

With respect to the seabed *dynamics*:

- From a combination of analyses on MBES survey data, ROV imagery of the Bluestream in October 2024 as well as morphological model computations it can be concluded that the seabed dynamics are limited to relatively small-scale bedform dynamics; there is no evidence for large-scale or local scale strong seabed bathymetric movements.

With respect to the seabed *morphology:*

- High resolution seabed maps produced from ROV data obtained during the execution of this study show the presence of small-scale ripples at the relatively shallow W5 Buitengaats OWF turbine area, whereas at the relatively deep B6 ZeeEnergie OWF turbine area, the seabed is more pock-marked suggesting the predominance of benthos shaping the seabed surface.

With respect to the seabed *sediment composition*:

- From laboratory analysis on 4 sediment samples obtained during the execution of this study, it follows that median (D50) sand sizes vary between 191 and 289 μm, with coarser grain sizes in the tail of the distribution (D90) varying between approx. 394 μm and 613 μm.
- Interestingly, 3/4 locations show a very sandy seabed (with only 1-2 % mud < 63μm), whereas west of the K8 turbine in the ZeeEnergie OWF, the seabed was observed to be vastly different, having a mud percentage of 42% mud. It is therefore strongly recommended to conduct a more spatial mapping of the seabed sediment composition, and including the Buitengaats OWF area, to infer whether this location/sample is an anomaly or relates to a mixed sand-mud layer of broader extent.

In conclusion, this study entailed the first steps towards a refined location selection of nature-enhancing projects in that it delivers on the general scarcity of field data related to high-resolution seabed morphology and sediment composition of the Gemini area. High-resolution seabed maps and seabed samples were produced, analysed and interpreted, thereby adding to our knowledge of both seabed morphology and sediment composition. This knowledge is necessary for site selection, as for example, oyster habitation is sensitive to both excessive sedimentation and grain size of the seabed.

Based on the results obtained herein, we advise the further combined studying of both relatively deep west-ZeeEnergie and relatively shallow east-Buitengaats area, along with the above-mentioned seabed sediment composition mapping on a larger scale, to infer the uniformity of the sand percentages and grain size distribution.

4 Bibliography

WaterProof, 2025. Modelling sediment transport in the Gemini ZeeEnergie OWF – Finding a cause for sedimentation at the WINOR oyster spat collector sites. Report WP1230_R3r0.