



Netherlands Enterprise Agency

IJmuiden Ver Wind Farm Zone

Sites Alpha and Beta

Project and Site Description

Final version, November 2023

>> Sustainable. Agricultural. Innovative. International.



This document has been produced for information purposes only and is not intended to replace any legal or formally communicated rules, regulations or requirements. More information on the site studies, including all reports and other deliverables mentioned in this PSD, can be found at offshorewind.rvo.nl when available.

Final version, November 2023

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Foreword

As a nation and as an industry, we have reached a pivotal moment in the development of offshore wind power in the Dutch North Sea. 2023 is the year the Netherlands achieves its ambition for 4.5 GW of offshore wind to be feeding power into the grid. It is also the year we accelerate into the fast lane of sustainable energy development. Starting in the IJmuiden Ver Wind Farm Zone, we are now moving forward with some of the biggest and most innovative individual offshore wind farms in the world to date.

Today, there is actually around 4.7 GW of offshore wind capacity installed in the Dutch North Sea. Our new national offshore wind goal is for 21 GW by 2030, as confirmed in the North Sea Programme 2022-2027.

To reach this, a rapid and cost-effective rollout of large-scale projects in the next few years is essential. The tenders for the IJmuiden Ver Alpha and Beta Wind Farm Sites, each 2 GW, kick off this new accelerated phase of development. The Roadmap Offshore Wind Energy 2030/2031 further outlines how we aim to fully achieve the 21 GW target. With wind power also at the heart of our ambition to be completely net zero by 2050, the increased momentum will go far beyond 2030 too.

The Dutch Government therefore remains steadfast in its support for the wind industry. We are, once again, taking a pro-active and collaborative approach as we take a giant leap into this new era of large-scale offshore energy development together. But it cannot be at any cost.

Our goal is to create a sustainable circular economy as we work to meet our net zero ambitions. So, as enshrined in the North Sea Agreement, it is our collective responsibility to safeguard and enhance our environment and society as we move forward. This requires maintaining a healthy balance between the energy, nature and food transitions. The IJmuiden Ver tender round reflects all of this and more. We increase our emphasis on qualitative criteria and innovation. For instance nature inclusive design and ecology, system integration, or responsible business operations along the supply chain.

As the first 4 GW of a new fleet of large-scale Dutch offshore wind farms, IJmuiden Ver Alpha and Beta are landmark projects by any number of measures. Located 62 km from the coast, where they cannot be seen from shore, they are further out to sea than our previous wind farms. Scaling up in the way we need requires extensive innovation, particularly when it comes to system integration and ecological design. That is why, for example, transmission system operator TenneT has worked with its industry partners to devise a new global benchmark for a standardised 2 GW offshore grid connection system. Using high voltage direct current cables, the innovative system will cost-efficiently convert and transport the energy generated by these huge wind farms to the onshore network.

We know tender bidders will also rise to the occasion. We are confident developers will bring bold innovations and optimisations into their designs, construction methods, and operations and maintenance plans. With this Project and Site Description (PSD), they now have the key specifications and site information they need to start designing these critical projects.

Of course, as we begin this accelerated phase of offshore wind development, there will undoubtedly be challenges ahead. But experience proves that together we can overcome them. In doing so, we will ensure our collective energy, ecological and economical objectives are achieved in a sustainable way and in time to meet our net zero goal.

Dr. M.G. (Michel) Heijdra
Director General for Climate & Energy
Ministry of Economic Affairs and Climate Policy



1. Objectives and reading guide



1.1 Objectives

This Project and Site Description (PSD) is for any party interested in participating in the planned tenders for permits to develop and operate projects at two wind farm sites (WFS) – Alpha and Beta – in the IJmuiden Ver Wind Farm Zone (IJVWFZ) in the Netherlands.

IJVWFS Alpha comprises the previously designated IJVWFS I & II and IJVWFS Beta comprises IJVWFS III & IV.

This PSD has been streamlined to provide a direct focus on project specifications and development requirements along with site data (including maps and tables) and site characterisation results. This PSD document therefore summarises the following:

- A description of the sites, surroundings, and characteristics of the IJVWFZ;
- Data collected by the Netherlands Enterprise Agency (RVO) regarding the physical environment of selected areas within the IJVWFZ;
- A selection of constraints, technical requirements, and permit related issues deemed to be most relevant for development of IJVWFS Alpha and IJVWFS Beta.

This document has been produced for information purposes only and is not intended to replace any legal or formally communicated rules, regulations, or requirements. More information on the site characterisation studies, including all reports and other deliverables mentioned in this PSD, can be found at offshorewind.rvo.nl.

Readers should note that information relating to the tender and permit process itself, as well as to the overarching legal frameworks and regulatory decisions pertinent to development of offshore wind projects in the IJVWFZ, will be made available after official publication in the Netherlands Government Gazette. Furthermore, publication of relevant laws and related tender documents and information can be found at rvo.nl/windenergie-op-zee. When the tenders are officially open, application forms and related documents will be available to download at mijn.rvo.nl.

The appendices related to this PSD (Applicable Law, Environmental Impact Assessment and Memo Boundaries and Coordinates) will be made available when completed. This can be found at offshorewind.rvo.nl.

1.2 Reading guide

This PSD is for IJVWFS Alpha and IJVWFS Beta. It presents an overview of all relevant project requirements and site information for parties interested in preparing to bid for a permit to build and operate a wind farm at these sites. The PSD covers the following aspects:

Chapter 1: Objectives and reading guide

Chapter 2: Offshore wind power development in the Netherlands
An overview on Dutch offshore wind development to date, including progress on achieving the goals of the Offshore Wind Energy Roadmap 2023 and 2030 and planning for post-2030 growth.

Chapter 3: IJmuiden Ver Wind Farm Zone – site description
General information on the IJVWFZ, its location, and surroundings. Work on the offshore grid connection system by transmission system operator (TSO) TenneT is also discussed.

Chapter 4: Site characterisation – studies and investigations
An updated overview of all the studies, surveys, and measuring campaigns performed to date on IJVWFS Alpha and IJVWFS Beta, as follows:

- Soil: Archaeological desk study, UXO risk assessment desk study, Geological desk study, Geophysical survey, Archaeological assessment of the Geophysical survey results, Geotechnical Site Investigation, Archaeological assessment of Paleo-landscapes, Ground Model, Morphodynamical and Scour Mitigation desk study;
- Wind and Water: Offshore Wind and Water Site Assessment, Metocean Measurement Campaign, Metocean assessment, Wind Resource Assessment.

Chapter 5: Resources for further information

Useful links for further information.

1.3 Site characterisation – quality and certification

1.3.1 Procedure

Assisted by independent experts, RVO managed the process for site characterisations of IJVWFS Alpha and IJVWFS Beta. It maintained a quality assurance procedure to provide accurate, practical, high quality studies.

First, the scope of the different studies was determined using the following steps:

1. RVO determined the preliminary scope of the different studies. Lessons learned from previous work on site characterisations for other wind farm zones – Borssele, Hollandse Kust (zuid), (noord), (west) and Ten noorden van de Waddeneilanden – were taken into account;

2. Where applicable, input was provided on these scope descriptions by internal experts, other government departments, agencies, external experts, and the industry;
3. During market consultation sessions, the scope descriptions were discussed with interested parties, with input on completeness provided by attendees;
4. The site characterisation deliverables were reviewed by internal experts from other government departments and external experts;
5. For studies where the results are inherently critical to developers for fundamental project design, the accredited certifying body DNV was contracted to confirm the completeness of the scope and results.

1.3.2 Procurement

The procurement of the different studies was carried out in compliance with the applicable procurement procedures within RVO. The desk studies have been procured through a limited tender where, for each study, at least two expert parties were invited to submit a proposal. Most of the site characterisations were procured through a public European tender. All proposals have been assessed by internal experts, other government departments, agencies, and external experts. Contractors were selected on the basis of determining the most economic advantageous offer, with safety, quality, and track record as the primary award criteria.

1.3.3 Quality assurance

After procurement, whilst work was being conducted by the specific contractor, quality assurance was performed as follows:

1. A project team, comprising RVO and external experts, was assigned for each study. The project team monitored the execution of the scope to ensure it was in compliance with the scope description;
2. Draft reports and other deliverables were reviewed by internal and independent external experts;
3. Where applicable, accredited certifying body DNV reviewed reports and other deliverables and provided a Verification Letter to assure the results were acquired in compliance with DNV-SE-0190:2023-03 and other applicable industry standards. Certification deliverables are added to the published reports where applicable.

At the time of publication of this final PSD, some site characterisation studies were still ongoing. RVO expects to secure an overall Statement of Compliance for the complete set of site studies once all final site characterisation studies are completed and the results published. An overview of the current status of the site studies and the certification process is provided in Section 1.3.4 of this PSD.

1.3.4 Certification status

Several site characterisation studies and investigations for the IJWVZ have been conducted. Table 1.1 shows the status of individual and overall certification by DNV.

Table 1.1 IJWVZ site characterisation studies and DNV certification status (Status 16 November 2023)

Site characterisations	Certification status	Overall Certification
Archaeological Desk Study	Quality approved	To be expected in Q2 2024
Archaeological Assessment	Quality approved	
Palaeoenvironmental Assessment	Quality approved	
Geophysical Survey	Quality approved	
Geological Desk Study	Quality approved	
UXO Desk Study	Quality approved	
Morphodynamics and Scour Mitigation Desk Study	Quality approved	
Metoccean Assessment	Study ongoing	
Metoccean Measurement Campaign	Study ongoing	
Geotechnical Survey Results	Quality approved	
Ground Model	Quality approved	

1.4 Experts and contractors

Experts and contractors that have provided input in the process include:

- BLIX Consultancy B.V. (project management, experts);
- DNV Netherlands B.V. – Royal Haskoning/DHV (experts);
- The Cultural Heritage Agency (experts, Archaeological desk study);
- Rijkswaterstaat (Experts, UXO desk study risk assessment);
- Arcadis Nederland B.V. (project management, experts);
- REASeuro (UXO desk study);
- Periplus (Archaeological desk study);
- GEOxyz BVBA (Geophysical survey)
- Stichting Deltares (Morphodynamical & Scour Mitigation desk study);
- Fugro (Geotechnical survey, Ground model);
- DHI A/S (Metoccean assessment);
- RPS Energy Ltd. (client reps Geophysical and Geotechnical survey);
- DNV Denmark for Certification deliverables;

1.5 PSD development

This Project and Site Description is developed and improved in cooperation with its users. We welcome feedback. Please send your feedback via woz@rvo.nl.

2. Offshore wind power development in the Netherlands

The Netherlands has come a long way since its first offshore wind farm, Egmond aan Zee, which came online in 2007. That wind farm comprised 36 turbines, each rated 3 MW, for a total capacity of 108 MW. Today, installed offshore wind capacity in the Dutch North Sea stands at just over 4.7 GW, exceeding the target set for 4.5 GW under the country's Offshore Wind Energy Roadmap 2023. Now, the Netherlands is aiming for at least 21 GW to be operating by 2030/31 and has also committed to implementing plans to boost that further by 2050 under various European agreements. Significantly, the most recent Dutch projects are in the gigawatt scale, are subsidy-free, and use 10 MW+ size turbines. To meet Dutch national and international commitments, however, a faster rollout of even bigger large-scale projects is now planned.

2.1 Successful completion of Roadmap 2023

A key step for Dutch offshore wind growth was the 2013 Energy Agreement for Sustainable Growth (Energieakkoord). This set binding targets for the uptake of renewable energy and the number of installed wind turbines in the Netherlands. The targets were for 14% of all energy to be generated from renewable energy resources by 2020, rising to 16% by 2023, with a goal for an additional 1,000 wind turbines to be installed.

Offshore wind was placed at the heart of policy strategy to meet the Energy Agreement targets. The country's first roadmap for development, Offshore Wind Energy Roadmap 2023, was published in September 2014. The Dutch Offshore Wind Energy Act, providing the legal regulatory framework, then came into force on 1 July 2015. Roadmap 2023 set out a schedule of tenders for a combined capacity of around 3.5 GW across three designated offshore wind farm zones – Borssele, Hollandse Kust (zuid) (HKZ) and Hollandse Kust (noord) (HKN). The aim was to provide long-term visibility of project pipelines and increase operational Dutch offshore wind capacity from around 1 GW at the time to 4.5 GW by end 2023.

With the Offshore Wind Energy Act, the Government adopted a proactive approach. State agencies, such as the Netherlands Enterprise Agency (RVO), play a central role in pre-development of sites and the tender process, while national transmission system operator (TSO) Tennet is responsible for the offshore grid. Overall, the aim was to reduce risk for investors and lower the cost of offshore wind by at least 40%. These goals have been achieved in time and well within budget, with the projects in HKZ and HKN (and those since) all being subsidy free.

2.2 Accelerated rollout to 2030 – Dutch and European commitments

In 2019, the Energy Agreement was incorporated into a more comprehensive National Climate Agreement, with the Dutch Climate Act signed into law. This was designed to meet the Netherlands' commitments under the Paris Agreement, targeting a 49% reduction in Dutch CO₂ emissions by 2030 and 95% by 2050, compared to 1990 levels. For electricity production specifically, the target was for net zero emissions by 2050. A new Dutch Offshore Wind Energy Roadmap 2030 was therefore published, this time aiming for around 11.5 GW operational offshore wind power by end 2030. Three new offshore wind farm zones were allocated under Roadmap 2030 – Hollandse Kust (west) (1.4 GW, subsidy-free tenders held in 2022), IJmuiden Ver (4 GW, to which this PSD relates), and Ten noorden van de Waddeneilanden (0.7 GW and recently designated for the world's largest offshore wind-to-hydrogen project to date, with the tender planned for 2026/27).

In the last three years, some key European policies and agreements have further shaped Dutch offshore wind policy. In 2020, the European Green Deal set a goal for all EU Member States to be climate neutral by 2050. A year later, the Fit-for-55 policy package increased the 2030 greenhouse gas emissions reduction target for Member States to a cut of 55% on 1990 levels. To achieve the increased 2030 emissions reduction target, the Dutch Government advised that an additional 10.7 GW of offshore wind capacity would potentially be required. Three new wind farm zones (Nederwiek, Lagelander and Doordewind) were designated for development of some of the extra capacity. This was reflected in the Additional Draft North Sea Programme 2022-2027 published by the Department of Infrastructure and Water Management in November 2021.

A new Additional Offshore Wind Energy Roadmap 2030 was then published in 2022, outlining project plans and tender schedules to reach at least 21 GW by 2030/31 (see map). The Government decided that more time was required to optimise the spatial planning for the Lagelander zone, with the potential for it to be used as an offshore 'multi-energy zone' post 2030 being investigated. It is therefore not included in the Additional Roadmap 2030.

To ensure timely delivery to meet the increased target, the decision was taken to increase the total capacity of projects to be included in each tender round. So, as this PSD outlines, this year a request for bids for two projects totalling 4 GW (2 GW at IJWFS Alpha, previously known as Sites I & II, and 2 GW at IJWFS Beta, previously Sites III & IV) is being made. Similarly, tenders for IJWFS Gamma (2 GW, formerly IJWFS V & VI) and Nederwiek WFS I (2 GW) will follow, currently planned for 2025. Dates for subsequent project tenders to complete the 21 GW target are still indicative (see map) and yet to be finalised, but all should be operational in 2030/31.

To cost-effectively and efficiently integrate these bigger 2 GW projects into the national grid, TenneT has produced a standardised, high voltage direct current 2 GW offshore grid connection system (see Chapter 3). This will be used for the first time in Dutch waters on the IJWFS Alpha and Beta projects.

2.3 Post 2030 development: hubs and hydrogen

Longer-term, future scenarios for Dutch energy systems (supply and demand) and the North Sea Energy Outlook (Noordzee Energie Outlook) published in 2020 indicated that the Netherlands will need 38-72 GW of cumulative offshore wind capacity by 2050. Meantime, Europe's ambition for offshore wind also increased in 2022. This was driven by energy security concerns arising from Russia's invasion of Ukraine as well as the need to ensure we meet our climate change commitments.

The Netherlands therefore signed the Esbjerg, Dublin and Ostend declarations:

- Esbjerg declaration (19 May 2022) – the Netherlands, Belgium, Denmark and Germany committed to reaching a combined target for installed offshore wind capacity of at least 65 GW by 2030 and 150 GW by 2050.
- Dublin declaration (12 September 2022) – the members of the North Seas Energy Cooperation (Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, Sweden and the European Commission) are currently members of the NSEC, since the withdrawal of the UK from the EU on 31 January 2020) agreed to reach a combined target of at least 260 GW of offshore wind by 2050.
- Ostend declaration (24 April 2023) – a follow up to the Esbjerg declaration, with the United Kingdom, France, Ireland,

Norway and Luxembourg joining the Netherlands, Belgium, Denmark and Germany in signing an updated agreement. The nine nations committed to reaching 120 GW of combined offshore wind capacity by 2030 and 300 GW by 2050. This will make the North Sea the world's biggest green power plant, the declaration noted.

On 16 September 2022, the Dutch Ministry of Economic Affairs and Climate Policy announced new offshore wind goals for the Netherlands specifically. It is now investigating the feasibility of reaching targets of 50 GW by 2040 and 70 GW by 2050, in line with the upper bandwidths in the future energy scenarios. These goals will be set in the National Energy System Plan. Going forward, a rolling roadmap will be used, updated regularly and as soon as new wind farm zones are identified. Insights from the Partial Revision of the North Sea Programme will be used as input to supplement the roadmap, it added. The next version of the North Sea Programme will be published in 2025.

Post 2030, the Government expects offshore wind farms will produce both electricity and hydrogen. Projects will also be located in larger areas further out in the North Sea. The Government will therefore work with a hub-based approach, whereby an integral assessment is made for these larger areas regarding the form (electrons or molecules) in which the generated energy can best be brought ashore. The North Sea Energy Infrastructure Plan 2050 (EIPN) is being worked on and will include a strategic picture of where the Government expects energy hubs and what infrastructure, including interconnectors to neighbouring countries, will be required.

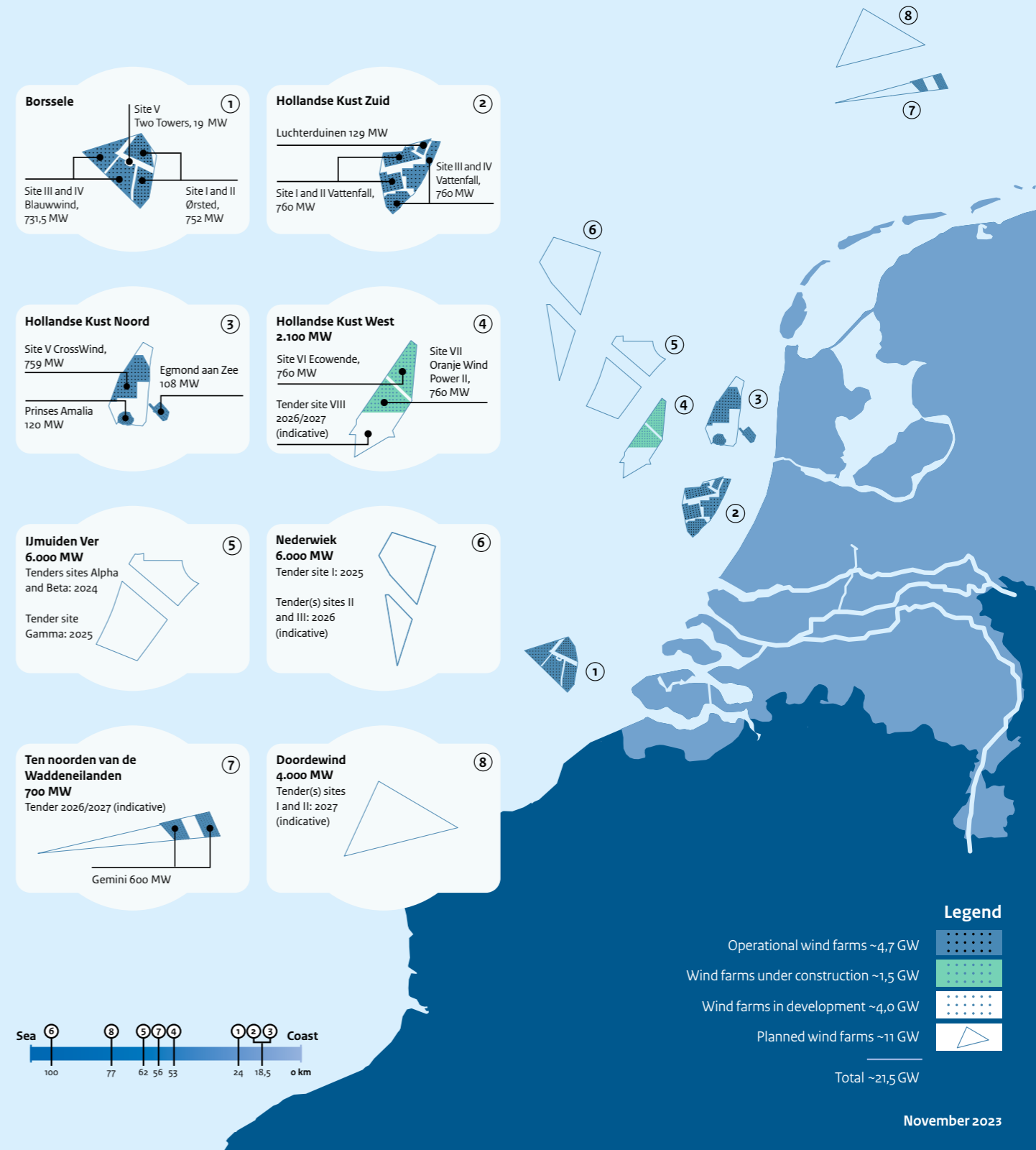
Further information about the current status of offshore wind in the Netherlands can be found in the Dutch Offshore Wind Market Report 2023, published April 2023.

2.4 Wind & water works

The Dutch Government participates in active knowledge sharing with foreign government agencies in Europe, as well as in Asia and America. It also works with the industry, knowledge institutions, and trade organisations to create new opportunities for our supply chain in the Netherlands and across the globe. Each year, we welcome foreign delegations and guests to the Netherlands for the Offshore Energy Exhibition and Conference (OEEC) in Amsterdam. During this three-day event, we share knowledge, network, present our innovative supply chain, and showcase new findings.

If you would like to connect with the Dutch Government, specific businesses, or knowledge institutions within our supply chain, please visit the wind & water works website (windandwaterworks.com) to find out more. We are keen to learn and share our knowledge with others.

Offshore Wind Energy Roadmap



3. Site description and offshore grid



3.1 General description of the IJmuiden Ver Wind Farm Zone

The IJmuiden Ver Wind Farm Zone (IJVWFZ) is located 33.4 nautical miles (62 km) off the west coast of the Netherlands in the Dutch North Sea. Three sites have been designated in the IJVWFZ: Alpha (formerly IJVWFS I - II), Beta (formerly IJVWFS III - IV) and Gamma (formerly IJVWFS V - VI). The upcoming permit tenders are for IJVWFS Alpha and IJVWFS Beta.

3.2 Layout and coordinates

The total combined surface area of IJVWFS Alpha and IJVWFS Beta (including the maintenance and safety zones) is approximately 650 km². The area includes safety zones and maintenance zones of infrastructure, for example active cables crossing the sites. This reduces the effective area available for new wind farm construction.

Each site within the IJVWFZ will accommodate 2 GW of offshore wind capacity.

TSO TenneT will construct two offshore substation platforms with grid connections for IJVWFS Alpha and IJVWFS Beta.

A table with coordinates for the boundaries of IJVWFS Alpha and IJVWFS Beta, maintenance zones, infield cable corridors, and safety zones will be published in Appendix C, Memo Boundaries and Coordinates, on offshorewind.rvo.nl.

3.3 Existing infrastructure

3.3.1 Cables and pipelines

There are several active and inactive existing cables and pipelines crossing the IJVWFZ. These can be seen in Figure 3.1. The description of pipelines and cables in the IJVWFZ can be found in Appendix C, which can be downloaded on offshorewind.rvo.nl containing a Word file and an Excel file.

3.3.2 Nearby Wind Farms

Sites within the Hollandse Kust (west), Hollandse Kust (noord) and Hollandse Kust (zuid) Wind Farm Zones are currently under development. Please consult developers of the projects within these zones when conducting activities in these areas. Coordinates can be found in Appendix C.

3.3.3 Offshore platforms and other nearby activities

There are several existing (mining) platforms and boreholes (both active and inactive) in or around the IJVWFZ.

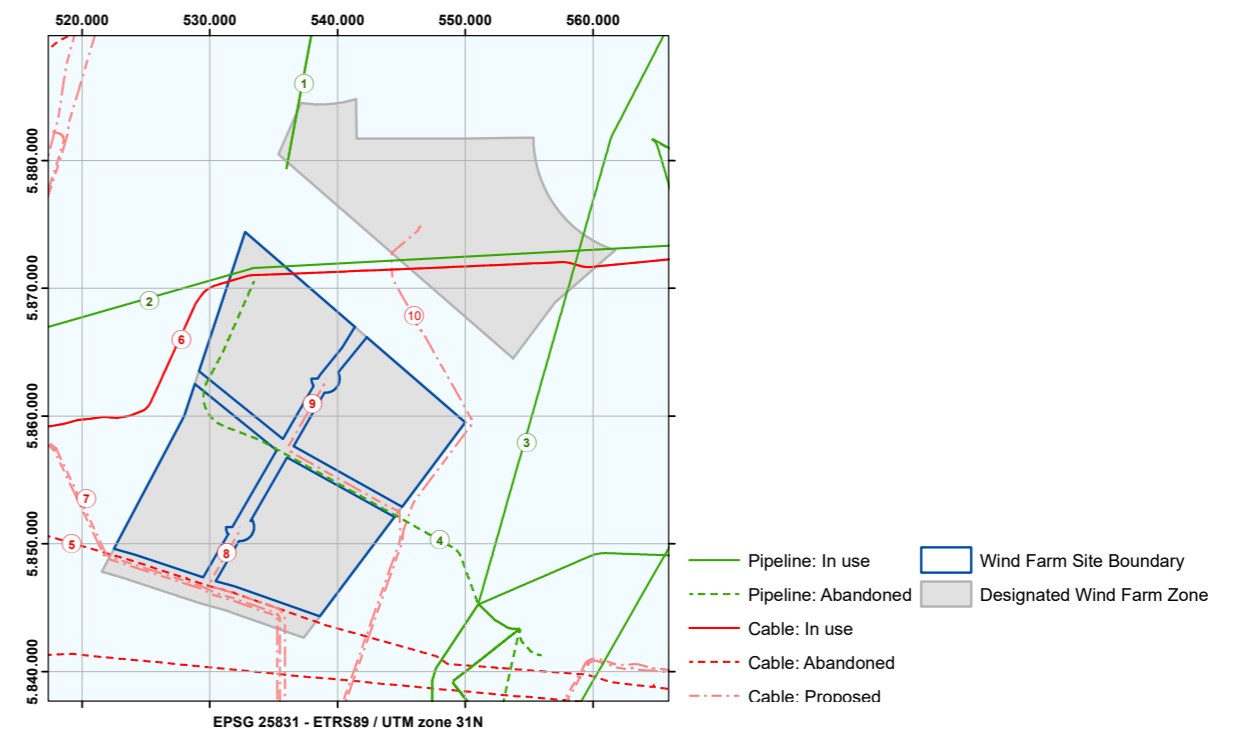


Figure 3.1 The IJmuiden Ver Wind Farm Zone and surrounding areas

3.3.4 Exclusion zones

A 500 m safety zone is defined around the IJWFZ. No construction ships or building activities are allowed in this safety zone. Pipelines and cables, including their maintenance zones (500 m on both sides of the pipelines/cables), are also excluded from the safety zone. Turbines need to be constructed and located in such a way that blade tips are within the site boundaries and outside the maintenance zones.

There are plans for a new shipping corridor (Newcastle – IJmuiden) across the IJWFZ. This shipping corridor, including the safety zone, is not currently planned to cross the Alpha and Beta sites, but this is still under negotiation as the Wind Farm Site Decisions are not final yet. Under the National Water Programme 2022- 2027, vessels up to 46 m can cross the entire area (under conditions).

3.4 TenneT offshore grid connection system

The Ministry of Economic Affairs and Climate Policy formally designated TenneT as offshore grid operator in the Netherlands on 6 September 2016. The Electricity Act 1998 introduced a 'Development Framework for the offshore grid', which provides a technical framework and outlines future development of offshore wind in the Netherlands.

The Development Framework for the offshore grid was published by the Ministry of Economic Affairs and Climate Policy and amended September 2018, May 2021, June 2022 and October 2023.

As prescribed in the Development Framework, TenneT will build grid connections for the new capacity required to meet the 2.1 GW offshore wind target planned under the Additional Offshore Wind Roadmap 2030/31.

To create economies of scale, TenneT will construct two standardised substation platforms, also called Alpha and Beta and each with a capacity of 2 GW. The planned locations of the platforms are shown in Figure 3.2, while Table 3.1 shows their coordinates.

Infield cables for electricity transmission from IJWFZ Alpha and IJWFZ Beta will connect directly to these platforms. Cable

entry zones are designated as the area to place infield cables connecting the wind farm to the platforms.

The IJmuiden Ver platforms will transform the output from the wind farms from 66 kV to 525 kV and transmit the electricity to shore through two 525 kV export cables. The export cables, will connect to the onshore substations and the 380 kV onshore grid. Details are in the Development Framework, which will be included in Appendix A of the final PSD. Contracts for platforms and cables have successfully been tendered by TenneT. A table in Appendix C shows the border coordinates of the export cable corridors.

3.5 Realisation Agreement and Connection and Transmission Agreement

In close consultation with the offshore wind industry, the Ministry of Economic Affairs and Climate Policy, the Authority for Consumers & Markets (ACM), and representatives of the Dutch energy market, TenneT has developed an offshore legal framework consisting of so-called model agreements. Consultation sessions on these model agreements were open to all stakeholders and completed ahead of the first subsidy tender process (2016). For IJmuiden Ver platform Alpha and Beta, TenneT has updated the model agreements to reflect the characteristics of the 2 GW HVDC system and held additional information sessions and a Q&A process.

The model agreements consist of a Realisation Agreement and a Connection and Transmission Agreement, supported by Offshore General Terms and Conditions, in line with onshore practice. All model agreements are available online (see tennet.eu/information-wind-farm-developers).

The model for these agreements will basically be the same for all winners of the tenders (past, present, and future). All agreements will enter into force according to the model agreements published by TenneT. The agreements will be concluded on an equal basis with the parties concerned. For the sake of completeness, the content of these agreements is non-negotiable. The final data in these agreements will be completed in close consultation with the parties with whom TenneT enters into agreements.

Table 3.1 Planned TenneT substation platforms for the IJWFZ

Platform center	Easting (x)	Northing (y)
Site Alpha (platform Alpha)	532359.5	5851358.4
Site Beta (platform Beta)	539056.3	5862970.3

Spatial reference: ETRS 89 / UTM Zone 31N; EPSG 25831

3.6 Applicable codes

The generic technical requirements for offshore wind farm connections are established as technical code requirements and, as such, are based on public law. In December 2018, ACM concluded and published a major revision of codes, affecting both onshore and offshore technical regulations. Further generic technical requirements by TenneT can be found in the annexes to the model agreements.

3.7 Step-by-step process to connection

RVO will, when requested, introduce the winner of the tender to the Ministry of Economic Affairs and Climate Policy, Directorate General for Public Works and Water Management (Rijkswaterstaat), and TenneT. After this introduction, TenneT will invite the winner for bilateral meetings to start the connection process. The necessary steps for connecting a wind farm to the offshore grid are as follows:

- The winner of the tender will provide TenneT with the data as indicated by TenneT in the Realisation Agreement and the Connection and Transmission Agreement;

- In case TenneT's 525 kV export cables and the offshore wind farm 66 kV cables should cross or are near each other, cable crossing and/or proximity agreements will need to be arranged between TenneT and the tender winner. TenneT will process the data received in the agreements and provide fully completed agreements to the winner;
- After the parties have signed the agreements, further information exchange and coordination will take place in the project working group (as referred to in Article 6 of the Realisation Agreement);
- The dates for completion of the platforms for IJmuiden Ver will be in the updated Development Framework, which will be included in Appendix A of the final PSD;
- RVO will hand over all remaining samples of the Geotechnical survey;
- Directorate General for Public Works and Water Management (Rijkswaterstaat) will coordinate the Maritime Information Services. Several sensors for public use will be placed on the platform.

Timely conclusion of the agreements is vital to ensure connection to the offshore transmission grid in line with the planning and to maximise cost reduction opportunities during the construction of the offshore grid, especially with regards to the platforms.

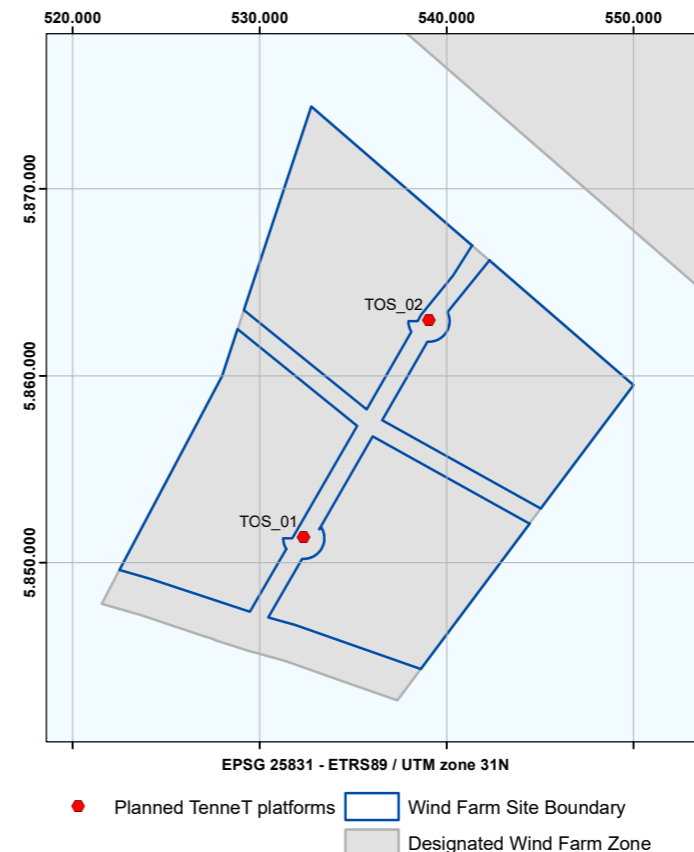


Figure 3.2 TenneT platforms Alpha and Beta, and maintenance zones in the IJmuiden Ver Wind Farm Zone

4. Site Characterisation

The Netherlands Enterprise Agency (RVO) is responsible for publishing the site information companies require to prepare bids for the permit tender for the IJWFZ. The site information package has sufficient detail and quality to be used as input for preliminary engineering design studies.

Results from previous tenders show this approach will provide the basis for an optimal tender result. In providing a more comprehensive data package, risk is significantly reduced for the developer, as is the need for conservatism in the assumptions of the tender design, while the business case for the project and the overall planning can be optimised. In this chapter, the scope of work and results of the individual studies and investigations are summarised, covering the following:

- Soil: Archaeological desk study, UXO risk assessment desk study, Geological desk study, Geophysical survey, Archaeological assessment of the Geophysical survey results, Geotechnical Site Investigation, Archaeological assessment of Paleo-landscapes, Ground Model, Morphodynamical and Scour Mitigation desk study;
- Wind and Water: Offshore Wind and Water Site Assessment, Metocean Measurement Campaign, Metocean assessment, Wind Resource Assessment.

Figure 4.1 shows how the various studies and investigations relate to each other as well to which element of the wind farm design they feed into. The findings of the Archaeological, UXO and Geological desk studies were used to define the scope of work and basis of the Geophysical site characterisation. The results of this comprehensive Geophysical site characterisation refine and partly supersede those of the three earlier desk studies and further feeds into the main Archaeological assessment, the Geotechnical site investigation and the Morphodynamical study.

Meanwhile, the Metocean Assessment, as a combination of the Wind Resource Assessment and the Metocean desk study, will take into account the intermediate findings of the Metocean measurement campaign.

Note: The IJWFZ Metocean Assessment, which includes the results of the Wind Resource Assessment, the Metocean desk study and the findings of the Metocean measurement campaign, will be finalised early January 2024 at the latest.

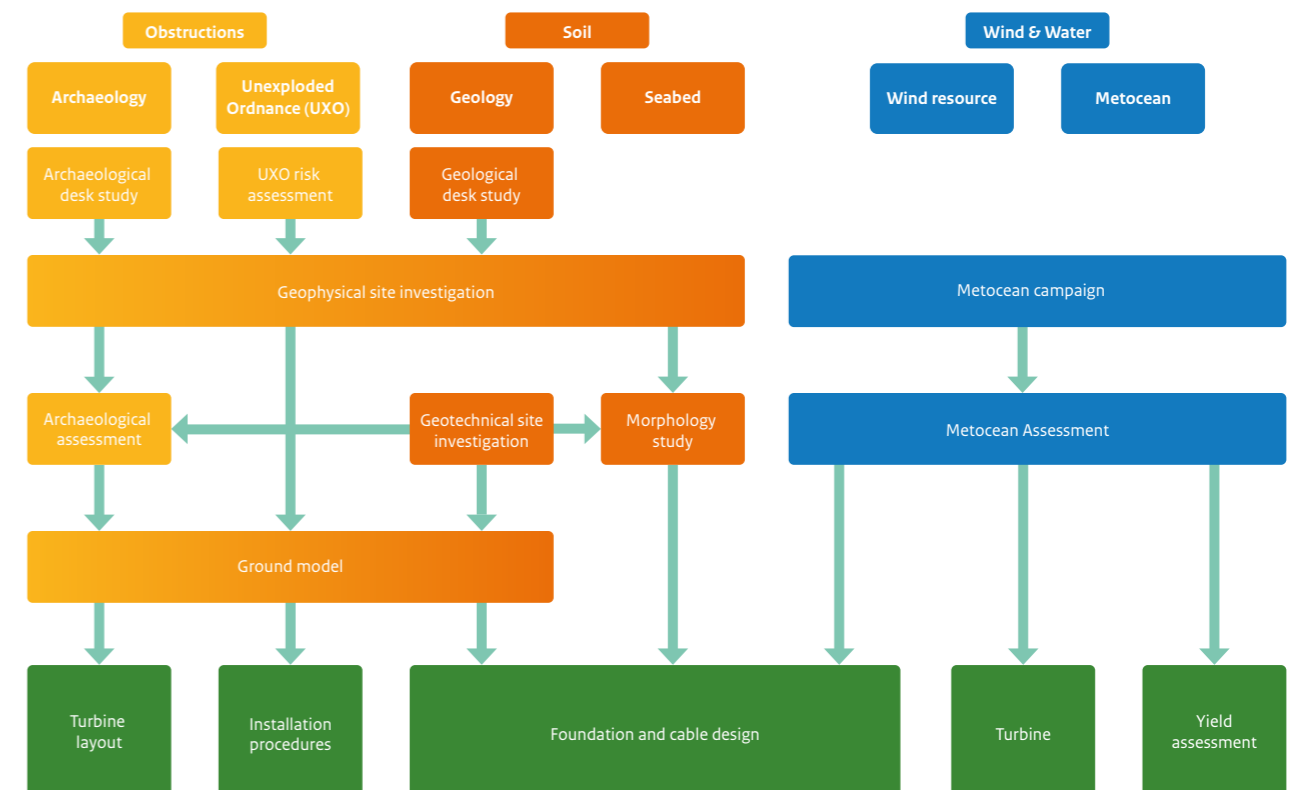


Figure 4.1 Site studies and investigations for the IJWFZ

4.1 Archaeological desk study

4.1.1 Aims and Objectives

The aim of the Archaeological desk study was to determine whether any archaeological remains are present in the IJWFZ, sites Alpha, Beta and Gamma, and, if so, whether they could be impacted by the development of the planned wind farms. The aim of the study was to assess the cultural-historical value of any discovered wrecks and objects of potential archaeological interest, prehistoric campsites, and inhumations.

4.1.2 Approach

The investigated area covered 1 349 km² located in the North Sea, 67 km off the coast of Petten. The desk study is the first step in the archaeological process and was conducted according to the Heritage Act 2016 (Erfgoedwet 2016). The research relied on database sources, as the Wind Farm Zone had not yet been investigated by detailed geophysical surveys. The team explored the presence of shipwrecks and WWII plane wrecks, as well as the likelihood of intact prehistoric landscapes, in situ remains of Palaeolithic and Early Mesolithic campsites, and inhumations. Further research was needed to determine the cultural-historical value of any discovered wrecks and objects of potential archaeological interest and to assess whether undiscovered shipwrecks are present.

4.1.3 Supplier

Periplus Archeomare was contracted by RVO to conduct the Archaeological desk study.

4.1.4 Results

The study identified 37 contacts in database sources within the investigated area. Of those, 19 are shipwrecks and 18 are objects, with just 1 wreck and 7 of the objects being of known archaeological value. The archaeological value of the remaining 18 shipwrecks and 11 objects is unknown. Further research is needed to determine the nature, extent, location, and age of the remains found at these sites.

Additionally, remains of in situ prehistoric campsites and inhumations are expected in the area, with the Boxtel Formation and Brown Bank Member being of particular interest. Along with these, the remains of Neanderthal campsites in the Borwn Bank Member can be expected and reworked flint artefacts from Lower and Middle Palaeolithic times in the ice-pushed deposits of the Formation 4.1.1. and Egmond Ground Formation. However, it is unlikely that prehistoric campsites will be identified with sufficient certainty to impose restrictions on wind farm developments. Instead, the focus should be on the pragmatic employment of geophysical techniques to obtain a better insight into the Pleistocene landscape.

To summarise, the area may contain undiscovered ship and plane wrecks and remains of prehistoric campsites, artefacts and inhumations.

4.1.5 Advice

In accordance with the AMZ (Archeologische Monumenten Zorg) cycle, a geophysical and geotechnical investigation is recommended. This should test the archaeological predictive model and further specify the type, vertical and lateral extent, age, integrity and potential archaeological levels.

4.1.6 Webinar

The results of the Archaeological desk study and the Archaeological assessment of the Geophysical survey results were presented and discussed at a webinar on 16 May 2023. Please refer to <https://offshorewind.rvo.nl> for details.

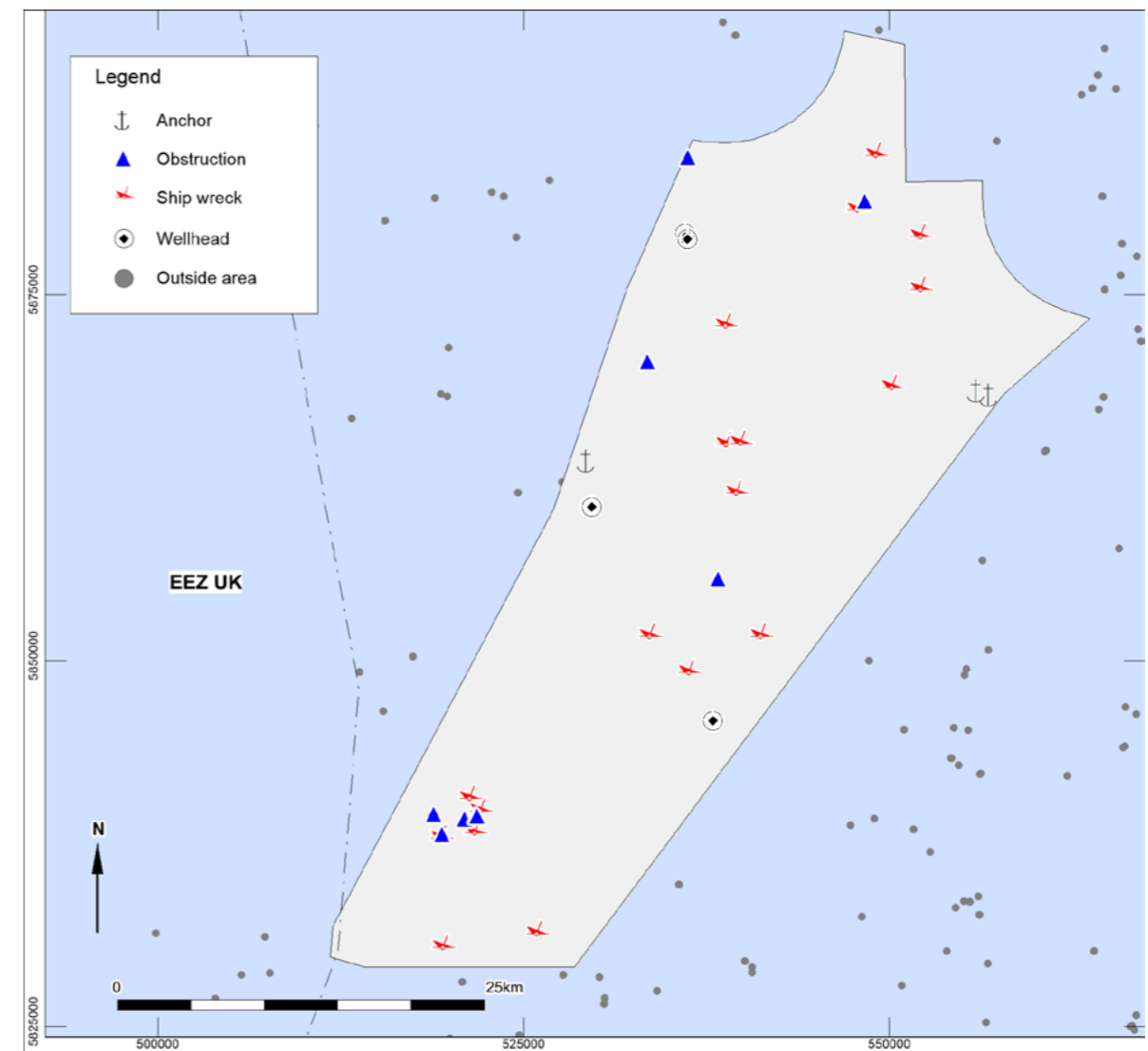


Figure 4.1.1 Summary of known contacts within the investigated area of the IJWFZ

4.2 Unexploded ordnance (UXO) risk assessment desk study

4.2.1 Overview - aims, objectives, and approach

The UXO desk study, performed in Q2 of 2019, provides initial insight into the risk of encountering unexploded ordnance (UXO). The main objectives of this study are:

1. Identify possible constraints for offshore wind farm related activities in the IJVVWFZ as a result of the presence of UXO.
2. Define specific requirements related to the presence of UXO for any wind farm related activity to be carried out in the IJVVWFZ. And identify areas within the IJVVWFZ that should preferably not be used for the installation of offshore wind farms and/or cables or any other structure.
3. Identify possible requirements from the UXO point of view that should be taken into account for:
 - a. Determining the different sites in the WFZ.
 - b. Conducting geophysical and geotechnical investigations.
 - c. Specific requirements (legal obligations, specific procedures) to be taken into account when finding UXO.
 - d. Installation of wind turbine foundations.
 - e. Installation of cables.
4. Identify whether any further investigations should be carried out regarding the presence of UXO and define the

scope of these investigations, including their spatial extent and timing within the overall site development programme – all relevant investigation methods will be considered for the project, from site investigation to installation.

4.2.2 Supplier

REASeuro performed the UXO desk study. The company specialises in (offshore) UXO desk studies, risk assessments, and UXO clearance operations. Since 2012, REASeuro has been involved with several offshore projects in the North Sea, performing data analysis, project risk assessments, and coordination of UXO clearance activities. Moreover, the company performed the UXO desk studies for the Borssele and Hollandse Kust (zuid), Hollandse Kust (noord) and Hollandse Kust (west) WFZs and export cable routes.

4.2.3 Results

The UXO risk assessment study consists of two sequential phases: historical research (1) and UXO risk assessment (2). The historical research delivers essential input for the risk assessment and subsequent mitigation strategies.

According to the historical research, the IJVVWFZ and surrounding areas were the scene of war-related activities during World War I (WWI) and World War II (WWII).

Historical research in The National Archives (London, United Kingdom) and Bundesarchiv-Militärarchiv (Freiburg, Germany) has shown that mining operations took place in and near the IJVVWFZ in WWI and WWII (Figure 4.2.1), but the mines were only partially recovered after both wars. The types of mines which may be present are German and British moored/contact mines from both WWI and WWII. It must be taken into account that this overview is based on the minefields actually present in (the vicinity of) the IJVVWFZ. Since the war, some ordnance is likely to have moved as a result of fishing, currents, and seabed dynamics. Other naval mines could be encountered, but is assessed as highly unlikely. The historical sources also state several incidents in regard to naval battles and submarine activity within the IJVVWFZ. As a result, UXO such as artillery shells and torpedoes are also likely to be encountered.

During the Allied bomber raids in WWII, a great many bombers flew towards targets in Germany or German occupied territory. In emergency situations or if finding the target failed, bomber crews often ditched remaining aerial bombs in the North Sea before returning to base. Furthermore, during WWII, German convoy routes were targeted by Allied bomber planes. To defend their shipping activities, the German navy (Kriegsmarine) used anti-aircraft artillery on small vessels such as their fast attack E-boats (Schnellboote). Taking into account the amount of air strikes on ships, jettisoned bombs and the use of anti-aircraft weapons, UXO such as aerial bombs, rockets, small

calibre munition and artillery shells might be present in the IJVVWFZ.

Based on this information, the entire WFZ is considered an area where a UXO encounter is possible (Figure 1).

After the historical research was performed, the risk assessment was conducted. The following parameters were assessed:

- Source, pathway and receptor
- Likelihood of presence
- Type of encounter
- Likelihood of occurrence
- Hazard severity

In assessing the overall UXO risks for the project, a Semi Quantitative Risk Assessment (SQRA) process was applied. The results of the risk assessment are shown in Table 4.2.1.

There is sufficient and indisputable evidence that naval mines might be present within the IJVVWFZ. There is also strong evidence indicating the presence of aerial bombs. The planned construction works may cause an aerial bomb or naval mine to detonate. A detonation is assessed to be 'possible' and may be initiated by, for example, crushing by a cable trencher during cable lay operations, a kinetic energy created during pile foundation operations, etc.

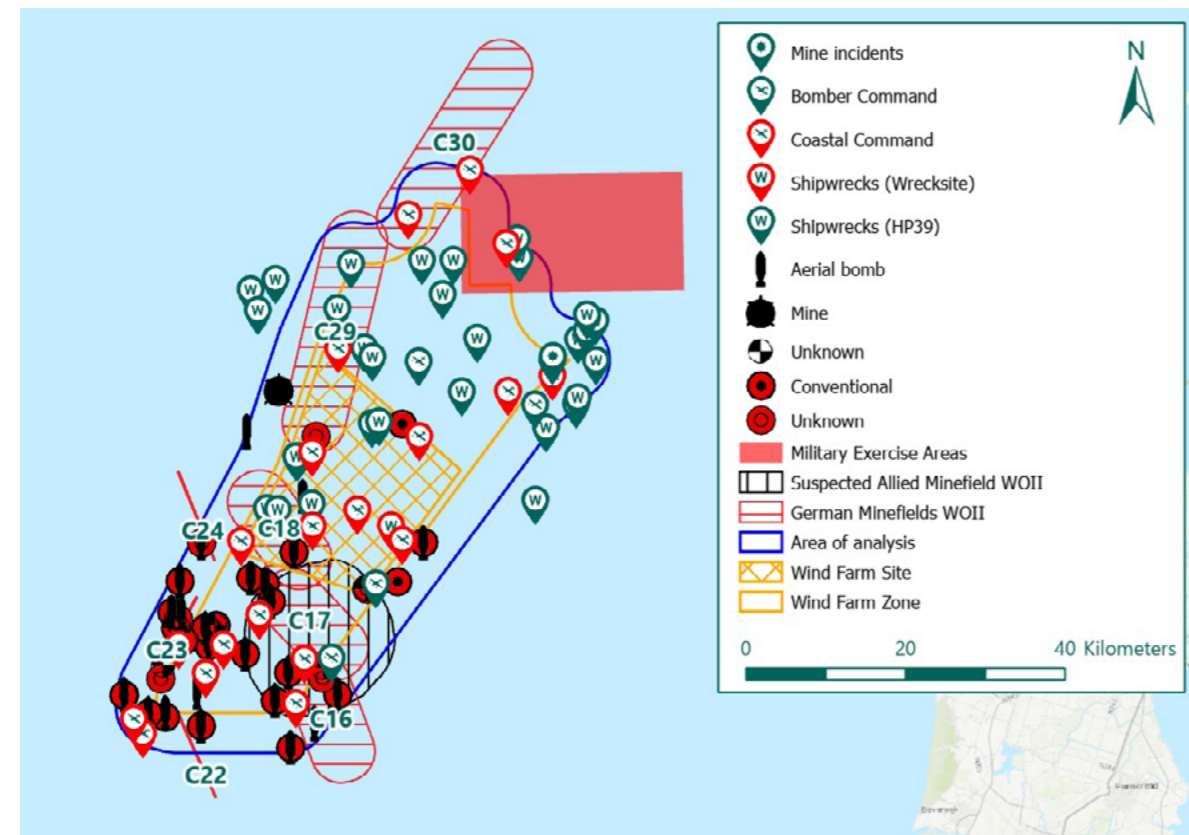


Figure 4.2.1 Overview of war related events within the IJVVWFZ (Source basemap: ESRI)

Table 4.2.1: Risk assessment results for the IJVVWFZ

Source	Likelihood of presence	Pathway	Receptor	Type of encounter	Likelihood of occurrence	Hazard severity	Risk result
Small Calibre Munition	Remote	Touch	Personnel Equipment	Primary	1 = Very unlikely	1 = Negligible	1 = LOW
Rockets	Remote	Touch	Personnel Equipment	Primary	2 = Unlikely	1 = Negligible	1 = LOW
Artillery shells	Feasible	Touch	Personnel Equipment	Primary	2 = Unlikely	1 = Negligible	1 = LOW
Torpedoes	Feasible	Touch, Movement, Vibrations, Magnetism	Personnel Equipment	Primary Secondary	3 = Possible	5 = Very High	15 = HIGH
Naval mines (WWI)	Feasible	Touch, Movement, Vibrations, Magnetism	Personnel Equipment	Primary Secondary	3 = Possible	5 = Very High	15 = HIGH
Naval mines (WWII)	Probable	Touch, Movement, Vibrations, Magnetism	Personnel Equipment	Primary Secondary	3 = Possible	5 = Very High	15 = HIGH
Allied aerial bombs	Probable	Touch, Movement, Vibrations	Personnel Equipment	Primary Secondary	3 = Possible	5 = Very High	15 = HIGH

In case of a detonation under water, the water column provides protection against fragmentation. The bubble jet and shock effect, however, may cause damage to vessels, compromising the integrity of the ship. Also personnel may be injured or killed due to the shock or sinking of a vessel. Artillery shells originating from naval attacks or dumping are likely to be present. These shells do not pose a significant threat for installation operations.

4.2.4 Conclusions and recommendations

Based upon the analysis of historical sources, it is evident that different war related events took place within and within the IJVVWFZ. Due to these events, the entire IJVVWFZ is considered a UXO risk area. A variety of UXO are likely to be present which includes aerial bombs, naval mines and artillery shells. The likely presence of UXO in the area, however, is not a constraint for offshore wind farm development. By applying professional UXO risk management, these risks can be reduced to a level that is considered As Low As Reasonably Practicable (ALARP).

Within the proposed area, there are no UXO risk free areas identified. However, since the entire IJVVWFZ is to be considered a UXO risk area and the risks posed by the presence of UXO can be sufficiently mitigated to ALARP, the entire IJVVWFZ can be selected for the installation of offshore wind farms and/or cables.

The possible effects of a detonation to vessels, equipment, personnel, and surroundings may form an intolerable risk. This means mitigation measures are required to reduce the risks to ALARP. In order to reduce the risk to ALARP, a dedicated UXO geophysical survey must be carried out to identify objects on the seabed that could potentially be UXO. The mitigation measures consist of UXO survey, identification of potential UXO objects, re-routing or re-location of cables and structure if possible, and disposal of UXO items if required.

Due to the highly dynamic soil morphology and possible associated migration and burial of UXO, it is recommended that companies conduct UXO search (and removal) operations immediately prior to construction activities at the intended construction locations. The limited temporal validity of the collected survey data should be taken into account when planning survey and construction operations.

Taking the results of the SQRA into account, it is assessed that the 250 lb bomb is deemed the smallest ferrous threat item for an ALARP sign-off. These items are cylindrical/tear-drop in shape, made of steel and, depending on the variant, contain between 30 and 60 kg of helium (HE). The ferrous weight can range from 50 to 83 kg dependent on the make, modification and type of munition. Assuming these items can be successfully detected and identified within the geophysical datasets, larger objects will also be detectable. The provisional magnetometer (MAG) threshold is set at 50 kg ferrous mass.

This threshold is also sufficient to detect ferrous naval mines which are likely to be present in the area. The risk also posed by the possible presence of depth charges, torpedoes and large calibre artillery shells will be mitigated sufficiently by applying the recommended threshold value.

4.2.5 UXO removal procedure

Within the Dutch Exclusive Economic Zone (EEZ), the Netherlands Explosive Disposal Authority (“Explosieven Opruimingsdienst”, EOD) is responsible for all maritime UXO disposal operations. If a wind farm developer identifies a UXO at a location where activities are planned, it needs to be removed. This should be reported to the Dutch Coastguard. The Royal Dutch Navy will dispose of the UXO. No disposal costs will be charged to the wind farm developer.

4.2.6 Webinar

The results of the UXO desk study were presented and discussed at a webinar on 16 May 2023. Please refer to <https://offshorewind.rvo.nl> for details.

4.3 Geological desk study

This study was the starting point for several other studies. However, more in-depth Geophysical and Geotechnical site investigations have since been conducted hence the desk study is not described further in this PSD.

4.4 Geophysical survey

4.4.1 Overview - aims, objectives, and approach

The aim of the Geophysical survey was to contribute to the bathymetrical, morphological and geological understanding of the IJVVWFZ. This survey follows on from the Geological, Archaeological and UXO desk studies and the results will provide information for the planning and preparation of Geotechnical investigations, and towards the creation of an Integrated Ground Model (IGM).

The objectives of this Geophysical survey were to provide:

- An accurate bathymetric dataset;
- Information describing all seabed features of significance to the construction of wind farm facilities, including:
 - Sea floor materials, their variation and morphology;
 - Any natural features such as boulders, scour hollows, pock-marks;
 - Anthropogenic features such as wrecks and debris pipelines, cables and infrastructure;
- Sub-seabed datasets of sufficient quality to support construction of a ground model to at least 100 m below seabed;
- A Preliminary Ground Model (PGM) of the site, including:
 - Estimated elevation and depth below seabed of the base of mobile sediments (if detectable);
 - Estimated elevation and depth below seabed for a set of interfaces between principal geological formations or other horizons of interest;
 - The locations of structural features or geohazards within the shallow geological succession;
- The current position of existing (in and out of service) cables and pipelines;
- A comprehensive interpretative report on the survey results obtained, describing the PGM.

The survey was carried out using GEOxyz’s vessels Geo Ocean II and Geo Ocean III between 8 April 2020 to 6 August 2020. Details of the vessel mobilisation, equipment verification and operations during the survey can be found in dedicated operations reports.

4.4.2 Supplier

GEOxyz BVBA was contracted by RVO to execute the Geophysical survey of the IJVVWFZ. GEOxyz was established in 1999 in Belgium and the GEO Group now encompasses entities in the UK, Belgium, France, The Netherlands, and Luxembourg. It offers a full range of marine survey, support and engineering services throughout Europe and provides specific project support all over the world. It provides services to authorities, the dredging, marine construction and offshore industry, consultancies and research centres.

GEOxyz owns a fleet of 22 vessels, which are equipped as required for each project using in-house owned survey equipment. All equipment is owned and maintained in-house. GEOxyz also uses its own specialised staff, advanced technologies and state-of-the-art survey systems.

4.4.3 Results and interpretation

4.4.3.1 Bathymetry and seabed morphology

Seabed levels within the survey area range from a minimum of 23.1 m below LAT along the crest of sandbanks to a maximum of 42.3 m below LAT in the south-west of the area.

The distribution of sandbanks, sandwaves and megaripples within the survey area is shown in Figure 4.4.1.

Seabed gradients of the sandbanks encountered within the survey area are in the region of 0.2-3.5°. Maximum gradients of the sandwaves are however much more variable across the survey area. The steepest gradients are noted in the southern and central portions of the area and these generally range from 5.5-9.9° whereas those in the northern portion of the survey area lie between 1.3° and 6.2°.

Seabed sediments across the majority of the IJVVWFZ survey area generally comprise of slightly silty sands and locally slightly silty gravelly sands, with varying quantities of shell fragments. Sediments in the south-western corner of the survey area are generally comprised of slightly silty to silty, gravelly to very gravelly sands.

4.4.3.2 Seabed features.

Unidentified Linear Scars and Trawl Scars

Two single track seabed scars were identified in the south-west corner of the survey area and had different characteristics than the trawl scars present throughout the area. Single Scar 1 is approximately 2690 m long, orientated NNE-SSW. On further inspection it appears there may be a parallel scar in places along the line. Single Scar 2 is a straight-line orientated east-west. It is 1407 m in length; it is broken in the centre section where the seabed sediment changes. These scars are not aligned with any known or unknown cables and pipelines within the survey area.

There are extensive fishing activities in the area with abundant transient trawl scars noted all across the survey area. Trawl scars are predominantly orientated in a north-south direction with other scars running close to east-west. Note, only selected trawl scars were picked to indicate spatial distribution across the survey area and any trends. The whole survey area should be treated as an area of trawl scars.

Surface contacts and magnetic anomalies.

A total of 1 23 isolated bathymetric features and 1 524 sidescan sonar contacts were identified across the survey area, interpreted as wrecks, debris, boulders and 'other' contacts. A total of 4893 magnetic anomalies were identified in the survey. 'Cable', 'pipe' and 'wreck' classifications were assigned where correlation could be made with existing information or a linear trend existed, as discussed in the following sections. A total of 3 795 anomalies are classed as Unidentified, of these 81 were correlated with a SSS contact. This would indicate potential ferrous debris on the seabed. However, any correlation is primarily based on proximity of the two contacts and, in many cases, they may not be directly related as the magnetic anomaly may equally be due to a buried object. The 1 81 anomalies classed as 'other' have been interpreted as possible geological feature. These were difficult to distinguish from the background field or had no clear monopole/dipole shape.

Where the same feature was identified in more than one dataset, it was given a designated feature ID. There were 207 cross correlated targets within the survey area, of which 6 wrecks have been identified (see Figure 4.4.2).

Cable and pipeline crossings

There are known to be two pipelines PL0176_PR and PL0125_PR and one cable, KBoo67 crossing the area. These are listed in Table 4.2.1. Pipeline PL0125_PR has been abandoned (although the side tap P2-SE is indicated to still be in use). There are a series of exposures along PL0176_PR as described below.

In addition to the known cables and pipelines above, a further 13 linear trends of magnetic field anomalies, interpreted as cables and cable fragments, have been found within the area. There are two main alignments: Unknown Cable 1 to the north and Unknown Cable 2 to the south. They both have a similar orientation to PL0176_PR (Figure 4.4.3) and extend across the whole area. There are also three unknown cable fragments. These are shorter sections with no alignment.

Unknown Cable 1 has been divided into sections 1A to 1H as there appears to be multiple sections of cable, some running parallel and some perpendicular. Further investigation is required to identify the origin of these magnetic anomalies.

4.4.3.3 Shallow soils and sub-sea geology (sub-bottom and UHRS)

The shallow sequence has been divided into seismostratigraphic units designated A to E. These are interpreted as corresponding to formal geological formations/members, as detailed in Table 4.2.2. However, in the absence of directly applicable geotechnical data (beyond the upper few metres), some uncertainty applies to some of the unit tops and bases and to the composition and characteristics of the sediments of each unit. There is also uncertainty over spatial variation within each unit.

Table 4.4.1 Known pipeline and cable crossings

Pipeline/Cable	Type	Route	Operator/Installation	Status
KBoo67	Fibre Optic	Egmond (NL) to Winterton (GB)	Cable and Wireless, Trenched	In Use
PL0125_PR	Gas 10-inch	P2-NE to P6-A	Wintershall Noordzee B.V.	Abandoned
PL0176_PR	Gas 36-inch	Balgzand (NL) to Bacton (GB)	BBL Company V.O.F.	Active

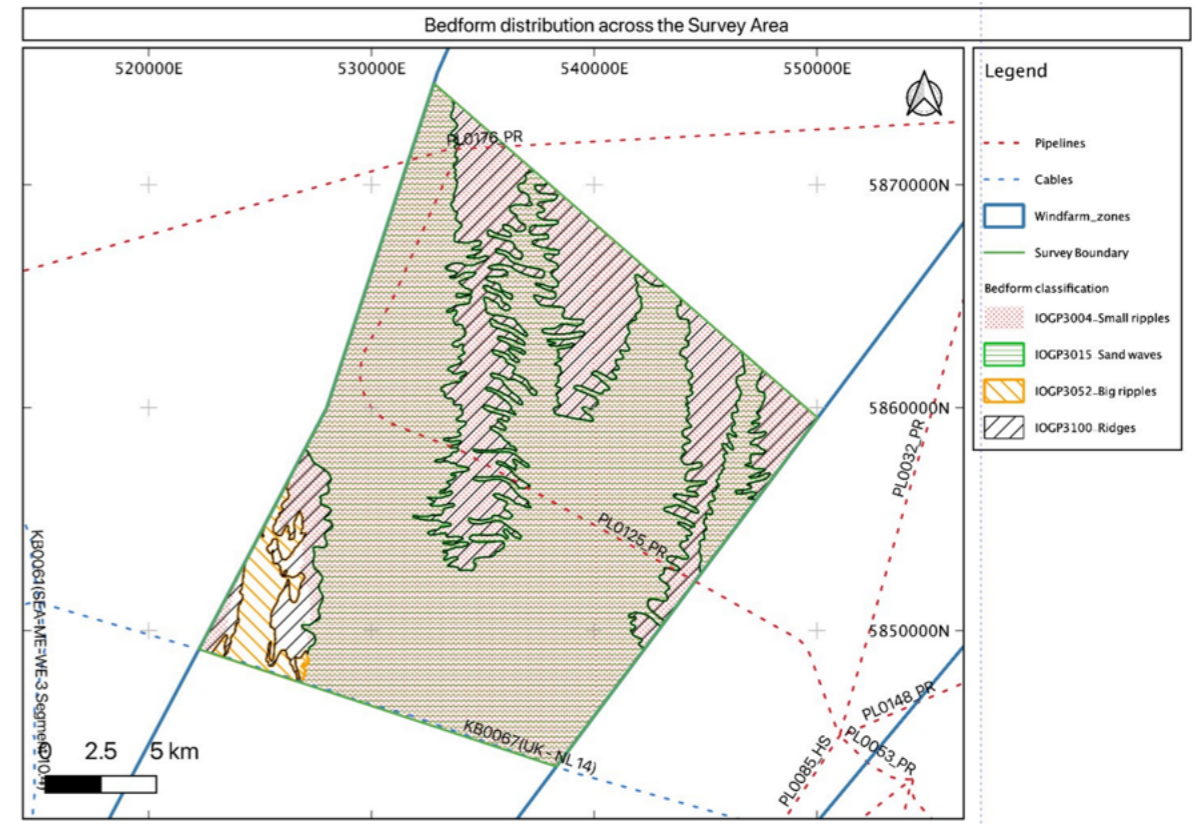


Figure 4.4.1 Bedform distribution

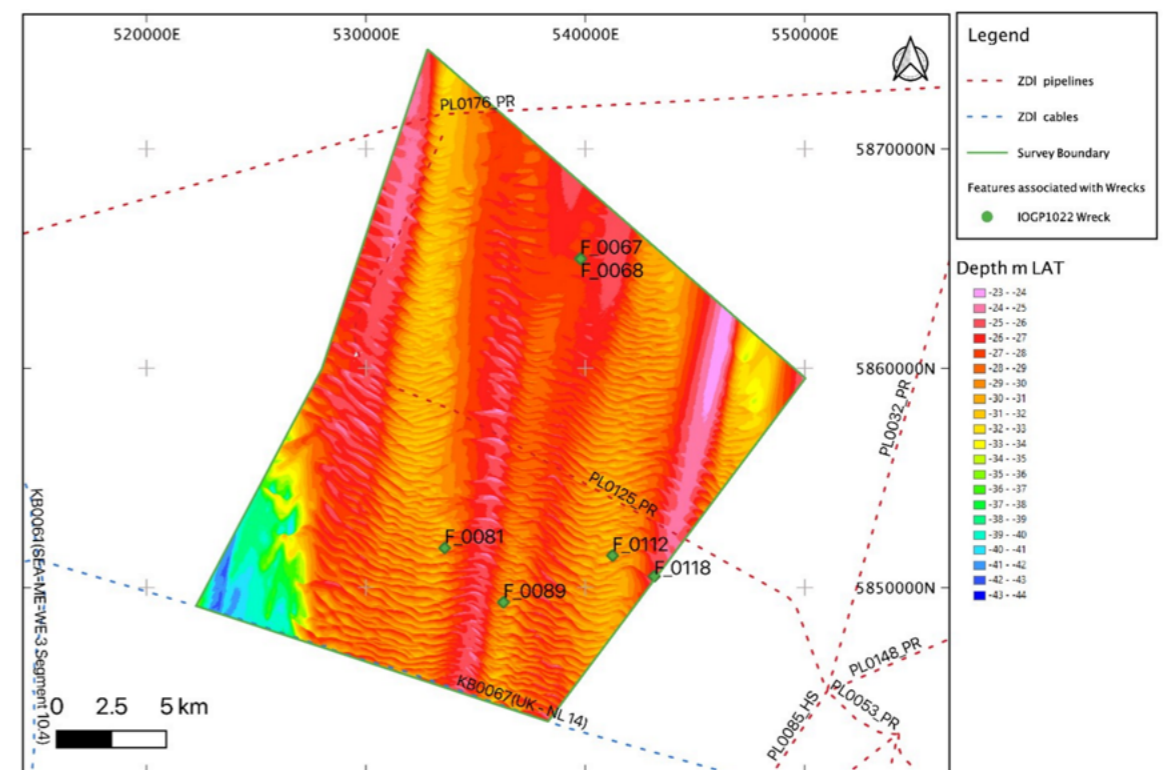


Figure 4.4.2 Distribution of wrecks and debris associated with wrecks

The exception to this pattern occurs in the south-west of the area where Units A and B terminate on the flanks of a broad bathymetric low.

The uppermost 100 m of sediments within the survey area are all relatively recent (Late Pleistocene and Holocene) and are overwhelmingly sand-prone, mainly comprising fine to medium grained sands which are locally calcareous. Occasional intervals are interbedded with marine clay or loam/peat.

This shallow sequence has been laid down under the influence of a pattern of glacial and interglacial cycles. The paleo-environment of the study area has undergone water depth variations ranging from subaerial exposure during glacial periods to interglacial water depths similar to those of today. Other variations include those related to the direct influence of ice, the movement of drainage systems and pathways and types of sediment supply/transport. The legacy of these changes is recorded by the diversity of shallow sequence.

A significant proportion of the recent sediments deposited in the area have been removed through erosion. H02 (at the base of Unit A) is a planar erosional surface, H05 (base Unit B) is an irregular erosion surface and H20 is a strong truncation surface which separates the Yarmouth Roads Formation from its overburden. The Yarmouth Roads Formation contains

numerous internal erosion surfaces. Therefore, the shallow sediments do not represent a continuous depositional record; the remaining sediments most likely represent early parts of depositional cycles as late phase deposits are the first to be removed once erosion begins.

The most significant contrast in the mapped units may be at the interface of the Yarmouth Roads Formation and all of the younger deposits (H20). The Yarmouth Roads sediments, though largely fluvial, underwent compaction by Saalian ice, whereas the younger deposits have not undergone direct ice loading (though they were laid down in a range of environmental conditions related to glacial cycles).

The geophysical data and seismic interpretation were used to plan a geotechnical campaign. The results from the ground truthing are integrated with further geological interpretation to produce a ground model (see Section 4.8) with soil types to better plan the future development of the wind farm sites.

4.4.4 Webinar

The results of the Geophysical survey IJWFZ were presented and discussed at a webinar on 23 May 2023. For details see <https://offshorewind.rvo.nl>.

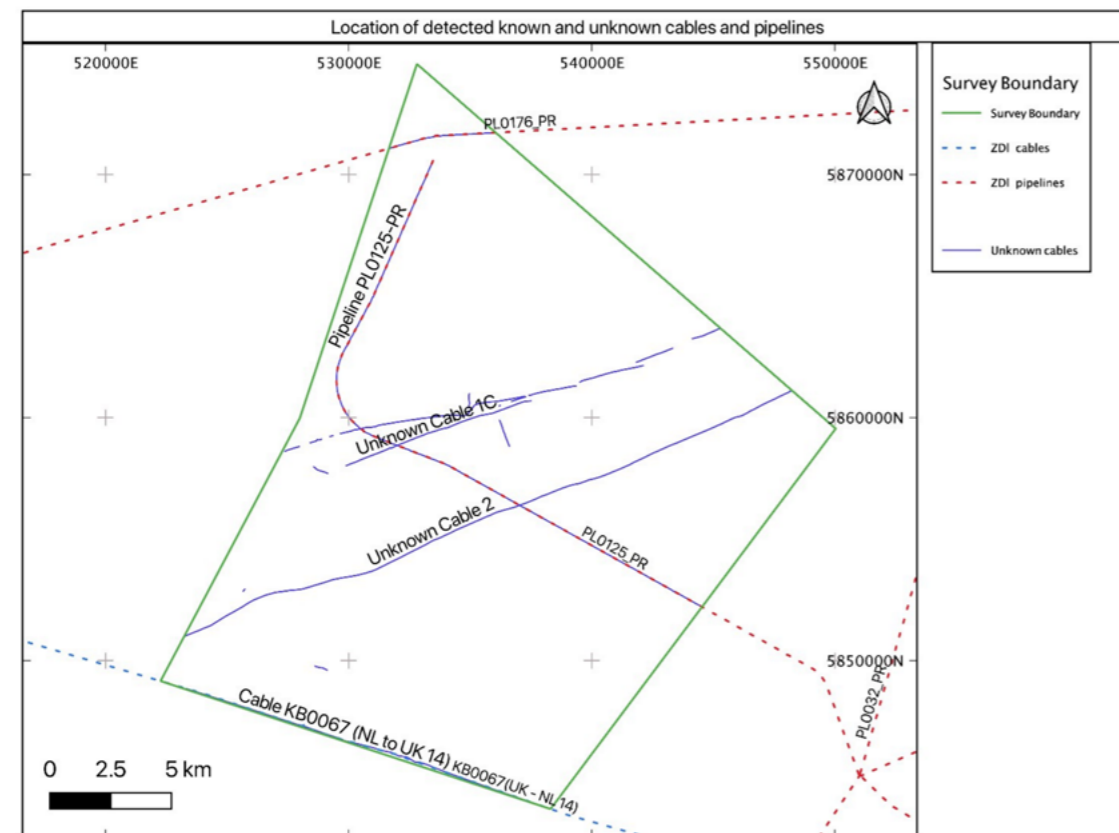


Figure 4.4.3 Location of known and unknown cable and pipeline crossings

Table 4.4.2 Preliminary Geological units identified in the survey area

Unit	Seismic Character	Distribution	Formation	Lithology
A	Acoustically amorphous, thickness varies due to mobile seabed, base is flat	2 m to 8 m thick, base at 29 m to 39.5 m LAT, absent in south-east corner of survey area.	Southern Bight (Bligh Bank M.)	Medium or fine to medium grained SAND with local clay laminae. Sparse gravel and shell fragments towards base.
B*	Distinct layering within channel feature	10 m - 22 m thick, base at 29 m to 47 m LAT, channel features in north of survey area	Naaldwijk	Fine grained muddy SAND with clay interbeds.
B	Featureless or weak reflections, high amplitude anomalies	10 m to 20 m thick, base at 29 m to 56 m LAT, absent in deepest areas to north-east and south-west corners of survey area	Naaldwijk	Fine grained muddy SAND with clay interbeds.
C	High amplitude laminations, lens structures, ambiguous interface with Unit D	4 m - 7 m thick, base at 29 m to 56 m LAT, locally absent where cut eroded by unit B	Eem (Brown Bank M.)	Partly consolidated silty CLAY and fine-grained SAND.
D	High amplitude laminations, lens structures, ambiguous interface with Unit C	4 m - 5 m thick, base at 33-49 m LAT, identified over whole area, locally absent where cut eroded by unit B	Eem/Egmond Ground	Medium to coarse grained SAND, SILT and silty SAND with 5% shells and locally 1-5% gravel (Eem). Shelly fine grained SAND with occasional peat (Egmond Ground).
E	Erosional top surface, progradational features, amorphous zones, high amplitude anomalies	Top of unit occurs at 33 m to 56 m LAT, present across whole area	Yarmouth Roads	Fine to medium grained non-calcareous SAND with occasional clay layers and peat.

4.5 Archaeological assessment of the Geophysical survey results

4.5.1 Aims

Following on from its initial work on the Archaeological desk study, Periplus Archeomare conducted an Archaeological assessment of Geophysical survey results to further investigate the presence of archaeological remains in the IJWFS Alpha and IJWFS Beta in the North Sea. The survey was conducted by GEOxyz, and although it was not primarily designed for archaeological research, a scan of the survey data acquired showed that the data is fit for an archaeological assessment. The overall goal of this assessment is to test the desk study-based expectancy for archaeological remains in the area, including shipping-related objects (wrecks), WWII airplanes, and prehistoric settlements.

4.5.2 Objectives

The objectives of this assessment are:

- To determine the historical or archaeological value of contacts found in the Geophysical survey;
- To validate the locations of known wrecks;
- To assess the prehistoric landscape based on the seismic data.

4.5.3 Approach

The approach for this Archaeological assessment involved analysing the Geophysical survey data obtained by GEOxyz using a range of methods, including side scan sonar (SSS), magnetometer (MAG), multibeam echo sounder (MBES), sub-bottom profiler (SBP), and ultra-high resolution seismic (UHR5). Before conducting the Archaeological assessment, the quality and completeness of the delivered survey data was evaluated. It was concluded that the data is of high quality and fit for the purpose of the Archaeological assessment. The approach for the assessment involved reviewing and analysing the survey data to identify potential archaeological features and remains, conducting desk-based research to contextualise the identified features and remains, validating the locations of known wrecks through comparison with historical records and additional research, assessing the prehistoric landscape through the analysis of seismic data, and producing a report of the findings that includes recommendations for further research or management of any identified remains.

4.5.4 Supplier

Periplus Archeomare was contracted by RVO to conduct an Archaeological assessment of the Geophysical survey results acquired by GEOxyz

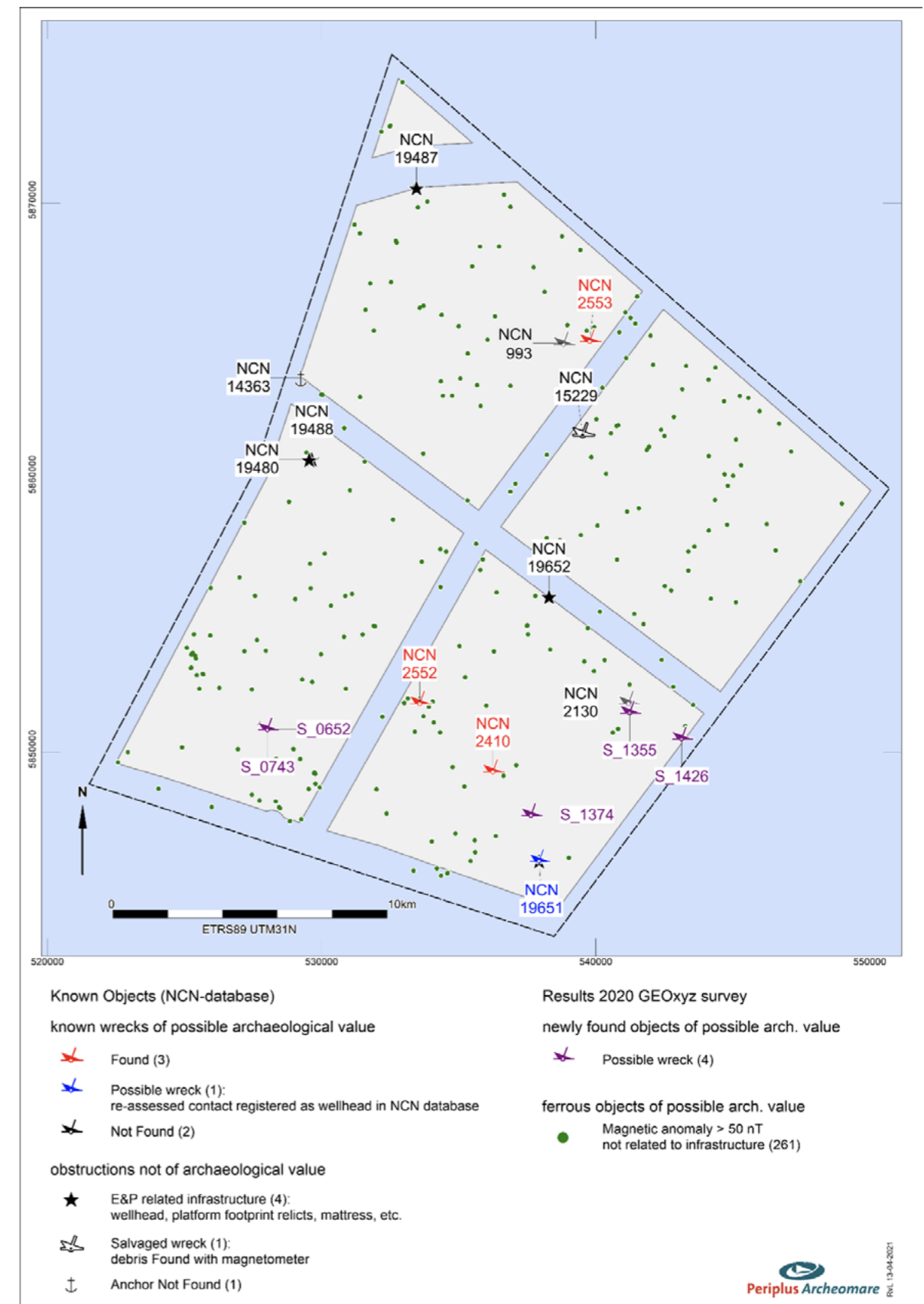
4.5.5 Results

The investigation involved an analysis of the Geophysical survey results as part of an Archaeological assessment. The survey covered a total area of 483 km² within the IJWFS. From the 12 known database objects reported in the Archaeological desk study, eight objects have been found during the Geophysical survey. Four of the eight known database objects are of possible archaeological value. Additionally, two objects with a possible archaeological value known from the database have not been found within the surveyed area and might be covered by sediments. Another 1550 SSS contacts were identified, in addition to the known objects. Further analysis of the SSS contacts identified four new possible wreck sites with possible archaeological value. The survey also revealed 5124 magnetic anomalies, of which 261 iron-bearing objects were found to have peak-to-peak values of 50 nT or more, possibly of archaeological interest.

The prehistoric landscape in the region primarily consists of Early Weichselian lagoonal and lacustrine deposits of the Brown Bank Member. Although Weichselian to Early Holocene (fluvio)periglacial deposits of the Bostel Formation were not identified in the seismic data, there may be local occurrences at the top of the Pleistocene. The Pleistocene landscape is covered by shallow marine sands and clays of the Naaldwijk Formation. In the northern part of the area, a younger channel incised the Naaldwijk Formation and locally the underlying deposits of the Brown Bank Member.

The seismic data indicates that a major part of the Pleistocene landscape has eroded during the Early Holocene marine ingression, potentially affecting the integrity of possible prehistoric settlements. Possible prehistoric remains in the area include campsites of hunter-gatherer communities, burials, tugboats, and lost or dumped flint and bone artefacts. The physical quality, integrity, and preservation of these remains are highly dependent on the extent to which archaeological levels have been affected by erosion.

Given the uncertainty surrounding the extent and preservation of possible prehistoric remains, further investigation and research are necessary to determine their archaeological value. It is recommended that seabed disturbing activities be avoided within an area of 100 m around the eight sites of potential archaeological interest until their value is determined. Additionally, during wind turbine and cable installation, a buffer zone of 100 m should be maintained around the 261 buried ferrous objects that induced anomalies over 50 nT. If it is not feasible to avoid the reported MAG locations, additional research is required to determine the actual archaeological value of the reported locations. The buffer zone may be reduced with approval from the Directorate General for Public Works and Water Management (Rijkswaterstaat), based on evidence that the applied disturbance has no effect on the archaeological object.



4.6 Geotechnical site investigation

4.6.1 Overview

The aim of the Geotechnical site investigation is to provide geotechnical data which improves the geological and geotechnical understanding of the IJWFZ and inform the design and installation requirements for offshore wind farms, including (but not limited to) foundations and cables.

The geotechnical campaign for the IJWFZ used intrusive techniques to gain insight into the characteristics of the subsoil. Three types of investigation techniques were used:

1. In situ testing from seafloor, consisting of standard, seismic, and temperature cone penetration testing and pore pressure dissipation testing;
2. Sampling from seafloor using a High Performance Corer® (HPC) sampling device; and
3. Geotechnical borehole drilling with downhole sampling, in situ testing consisting of standard and seismic cone penetration testing, recording of drilling parameters, and borehole geophysical logging (caliper, natural gamma radiation, spectral gamma radiation, P and S suspension logging, downhole magnetic resonance, and resistivity).

The site investigation at the IJWFZ comprised the following:

- A total of 252 seafloor piezocone penetration tests (PCPTs) at 235 target locations to depths ranging from seafloor to 60.5 m below seafloor (BSF);
- A total of 61 seafloor seismic cone penetration tests (SCPTs) at 51 target locations to depths ranging from 4.0 m to 60.4 m BSF, of which 58 test points included seismic velocity tests (SVTs);
- A total of 69 seafloor temperature cone penetration tests (TCPT) at 68 target locations to depths ranging from 2.4 m to 6.8 m BSF, of which 69 test points included temperature equilibrium tests (TETs);
- A total of 137 pore pressure dissipation tests (PPDTs) at 108 target locations. PPDTs were performed at selected depths within a seafloor PCPT stroke or seafloor SCPT stroke;
- A total of 186 vibrocores at 176 target locations to depths ranging from seafloor to 6.6 m BSF;
- A total of 151 geotechnical boreholes at 114 target locations to depths ranging from seafloor to 83.0 m BSF. Boreholes including any combination of the following: open hole rotary drilling, recording of drilling parameters, downhole in situ testing, downhole (over)sampling, or alternating downhole in situ testing and (over)sampling, and/or borehole geophysical logging;
- Eleven boreholes included sampling for biogeochemical analyses and thirteen boreholes included sampling for geological dating analyses;

- Twenty boreholes at ten target locations included borehole geophysical logging.

The term 'location' used in this document refers to a specified target location. A location can consist of a single or multiple boreholes, test points, or sample points whereby the term 'borehole' is defined as a geotechnical borehole with associated downhole sampling, downhole in situ testing, and/or borehole geophysical logging, 'test point' as a seafloor cone penetration test (CPT), and 'sample point' as a sampling from seafloor operation. Boreholes, test points, and sample points designated with a suffix 'A' or 'B' refer to additional operations at a specific location.

An overview of the standard and advanced laboratory test programmes can be found in Table 4.6.1 and Table 4.6.2. Note that determinations of water content and unit weight, and torque and pocket penetrometer tests are not presented in these tables.

4.6.2 Supplier

Fugro was contracted to perform this Geotechnical site investigation. The site investigation was performed according to ISO 19901-8:2014 and was conducted in two separate campaigns using geotechnical vessel 'Despina' and geotechnical drilling vessels 'Normand Flower' and 'Fugro Synergy' between 3 February and 16 September 2021.

4.6.3 Approach

A SEACALF® 20 tons MkV Constant Drive System (CDS) was used for seafloor in situ testing. PCPTs, SCPTs, and PPDTs were performed using cone penetrometers with a 1500 mm² cone tip area. TCPTs were performed using cone penetrometers with either a 1000 mm² or 1500 mm² cone tip area. The SEACALF® CDS provided a reliable, safe, and efficient test unit for high quality data acquisition. Sampling from seafloor was performed using a HPC® sampling device equipped with a 6.4 m core barrel and an inner PVC liner to contain the sample.

The geotechnical boreholes were performed using open hole rotary drilling in combination with Pure-Bore®, guar gum, and/or water as drill fluids. Borehole drilling included the use of a SEACLAM seabed frame ('Normand Flower') or a SEADEVIL® seabed frame ('Fugro Synergy') to facilitate re-entry of the drill string in the borehole and for axial and lateral support of the drill string at seafloor. Downhole push sampling and in situ testing employed WIPSAMPLER® and WISON® downhole tools. The sampler was fitted with flush stainless steel Shelby tubes. Downhole tools were operated and retrieved by a hydraulic-electrical umbilical system which provides real-time control of the in situ testing and sampling process. Downhole CPTs were performed using cone penetrometers with a 1000 mm² or 500 mm² cone tip area. Downhole SCPTs were performed using dual array seismic cone penetrometers. The seismic source consisted of a hydraulic underwater shear wave hammer, consisting of a spring-driven steel mass hammered to a steel striking plate, mounted on the seabed frame.

Table 4.6.1 Overview of standard laboratory test programme

Test Type	Test Quantity
Geotechnical Index	
Particle density	166
Particle size distribution: sieving and sedimentation	2133
Particle size distribution: dynamic image analysis	1272
Particle shape: dynamic image analysis	1272
Minimum and maximum index dry density: (modified) shaker method	191
Minimum and maximum index dry density: DGF method	10
Atterberg limits	382
Sample microscopic photography	157
Geochemical	
Organic matter content: dichromate oxidation	191
Mass loss on ignition	13
Strength and Stiffness	
Unconsolidated undrained triaxial compression: undisturbed	73
Unconsolidated undrained triaxial compression: remoulded	63
Isotropically consolidated undrained triaxial in compression	78
Isotropically consolidated undrained triaxial in compression with cyclic pre-shear	17
Anisotropically consolidated undrained triaxial in compression	51
Anisotropically consolidated undrained triaxial in extension	22
Isotropically consolidated drained triaxial in compression	440
Isotropically consolidated drained triaxial in compression with cyclic pre-shear	21
Direct simple shear: constant volume	134
Direct simple shear with cyclic pre-shear: constant volume	20
One-dimensional Consolidation	
Incremental loading	67
Constant rate of strain	45
Permeability	
Constant head permeability: permeameter	188
Constant head permeability: triaxial cell	24
Interface Shear Angle	
Ring shear	121
Other	
Thermal conductivity	164
Transient plane source	173
Geological dating analyses	875*
Microbiological analyses	48

* = various analyses performed

Table 4.6.2 Overview of advanced laboratory test programme

Test Type	Test Quantity
Geotechnical Index	
Particle density	10
Particle size distribution: sieving and sedimentation	7
Particle size distribution: dynamic image analysis	8
Particle shape: dynamic image analysis	8
Minimum and maximum index dry density: (modified) shaker method	10
Atterberg limits	5
Sample microscopic photography	10
Strength and Stiffness	
Isotropically consolidated undrained triaxial in compression with bender elements measurements	6
Isotropically consolidated undrained triaxial in compression with cyclic pre-shear and with bender elements measurements	7
Isotropically consolidated drained triaxial in compression with cyclic pre-shear and with bender elements measurements	5
Direct simple shear: constant volume	10
Direct simple shear with cyclic pre-shear: constant volume	19
Direct simple shear with cyclic pre-shear: constant vertical stress	11
Permeability	
Constant head permeability: permeameter	14
Constant head permeability: triaxial cell	6
Cyclic Strength and Response - Triaxial	
Isotropically consolidated undrained cyclic triaxial	9
Isotropically consolidated undrained cyclic triaxial with cyclic pre-shear	22
Isotropically consolidated cyclic triaxial with drainage with cyclic pre-shear	6
Cyclic Strength and Response – Direct Simple Shear	
Cyclic direct simple shear	22
Cyclic direct simple shear with cyclic pre-shear	103
Dynamic Response	
Resonant column single stage	7
Resonant column multi-stage	12

For a selection of geotechnical boreholes, following completion of open hole drilling, downhole sampling and/or in situ testing, the drill bit was pulled up to a minimum safe depth with respect to the risk of borehole collapse. This allowed open hole acquisition of borehole geophysical data by lowering the downhole geophysical tools through the bit into the open hole. At each location multiple runs were executed, employing a suite of wireline conveyed downhole geophysical tools (caliper, natural gamma radiation, spectral gamma radiation, P and S suspension logger, downhole magnetic resonance, and resistivity).

4.6.4 Results

Results of the Geotechnical site investigation are presented in various reports, as outlined below.

A geotechnical report containing geotechnical logs based on CPT results and results from seafloor in situ testing, including:

- Interpretation of soil profiles and CPT-derived parameters including relative density and undrained shear strength;
- Measured and derived CPT parameters including cone resistance, sleeve friction, pore pressure, temperature, friction ratio, pore pressure ratio, thermal conductivity, and heat capacity, where applicable;
- Results of SVTs, i.e. recorded seismic traces (X- and Y- channel), and derived shear wave velocity and small strain shear modulus;
- Results of TETs, i.e. temperature versus time, and derived thermal conductivity;
- Results of PPDTs, i.e. cone resistance and pore pressure versus time;
- Horizontal projection of CPT trajectories.

Figure 4.6.1 presents an example of a geotechnical log based on CPT results.

A geotechnical report containing geotechnical logs and results from seafloor sampling and laboratory testing, including:

- Interpretation of soil profile and strata descriptions based on available data sources, including sample descriptions and laboratory tests;
- Results of laboratory tests.

Figure 4.6.2 presents an example geotechnical log based on results from seafloor sampling and in situ testing, and standard laboratory testing.

Two geotechnical reports containing geotechnical logs and results from downhole sampling and in situ testing, borehole geophysical logging, and standard laboratory testing, including:

- Interpretation of soil profiles, strata descriptions, and CPT-derived parameters including relative density, undrained shear strength, and effective angle of internal friction;
- Measured and derived CPT parameters including cone resistance, sleeve friction, pore pressure, friction ratio, and pore pressure ratio, where applicable;
- Results of SVTs, i.e. recorded seismic traces (X- and Y- channel), and derived shear wave velocity and small strain shear modulus;
- Results of borehole geophysical logging including natural gamma radiation measurements, caliper measurements, spectral gamma radiation measurements, P- and S-wave velocities, resistivity, porosity, as well as derived hydraulic conductivity and derived soil unit weight;
- Results of laboratory tests;
- An examination report containing estimation of microbially influenced mass loss rates of steel-based foundation structures in marine sediments on the basis of chemical and microbiological soil parameters.

Figure 4.6.3 presents an example geotechnical log based on results from downhole sampling and in situ testing, and standard laboratory testing.

A geotechnical report containing results of the advanced laboratory testing programme. The results are from the following:

- Geotechnical index tests;
- Microscopic photography;
- Static triaxial tests;
- Monotonic direct simple shear tests;
- Permeability tests;
- Cyclic triaxial tests;
- Cyclic direct simple shear tests;
- Resonant column tests.

A dating analysis report containing results of dating analyses and results of a geochronology and palaeoenvironmental assessment for selected seafloor sample locations.

A dating analysis report containing results of dating analyses and results of a geochronology study for selected geotechnical borehole locations.

In addition to the above, digital data files accompanying the various reports are also issued. These data files comprise the following data types:

- AGS 4.0: CPT data, geotechnical borehole data;
- ASCII: CPT data, SVT data, TET data, PPDT data, records of drilling parameters;
- ACI: shear wave velocity trace data;
- LAS: borehole geophysical logging data;
- Excel: coordinates and water depths, overview of laboratory test results, individual laboratory test results.

4.6.5 Webinar

The results of the Geophysical and Geotechnical site investigations performed at the IJWFZ were discussed in webinars on 23 and 25 May 2023. Please refer to <https://offshorewind.rvo.nl> for details.

4.6.6 Conclusion

The Geotechnical site investigation and associated laboratory testing programme provide high quality geotechnical data which improves the geological and geotechnical understanding of the IJWFZ and progresses the design and installation requirements for offshore wind farms, including (but not limited to) foundations and cables. The samples remaining after the laboratory testing phase will be available to the winning developers, e.g. to perform additional testing. The reports have been certified by DNV.

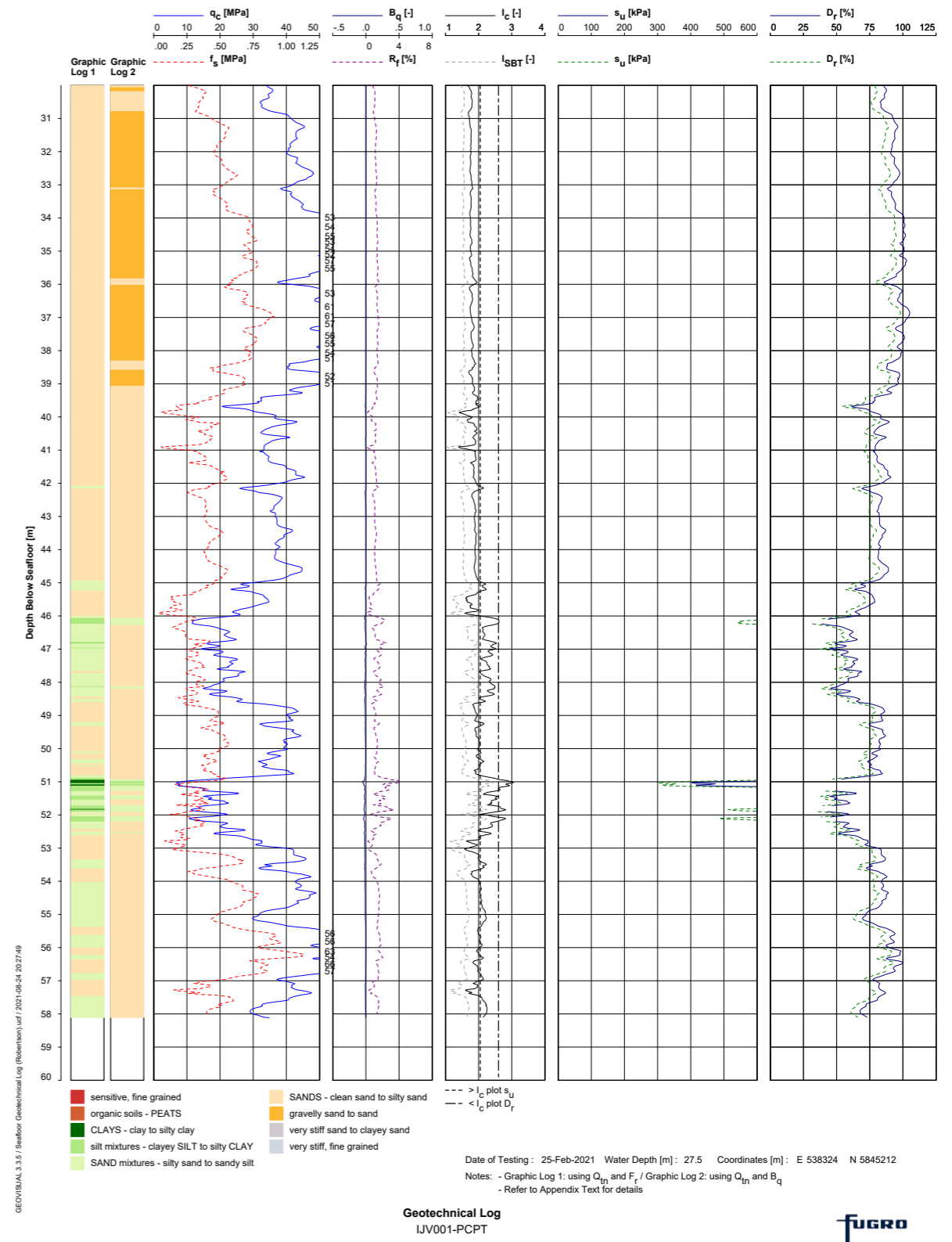
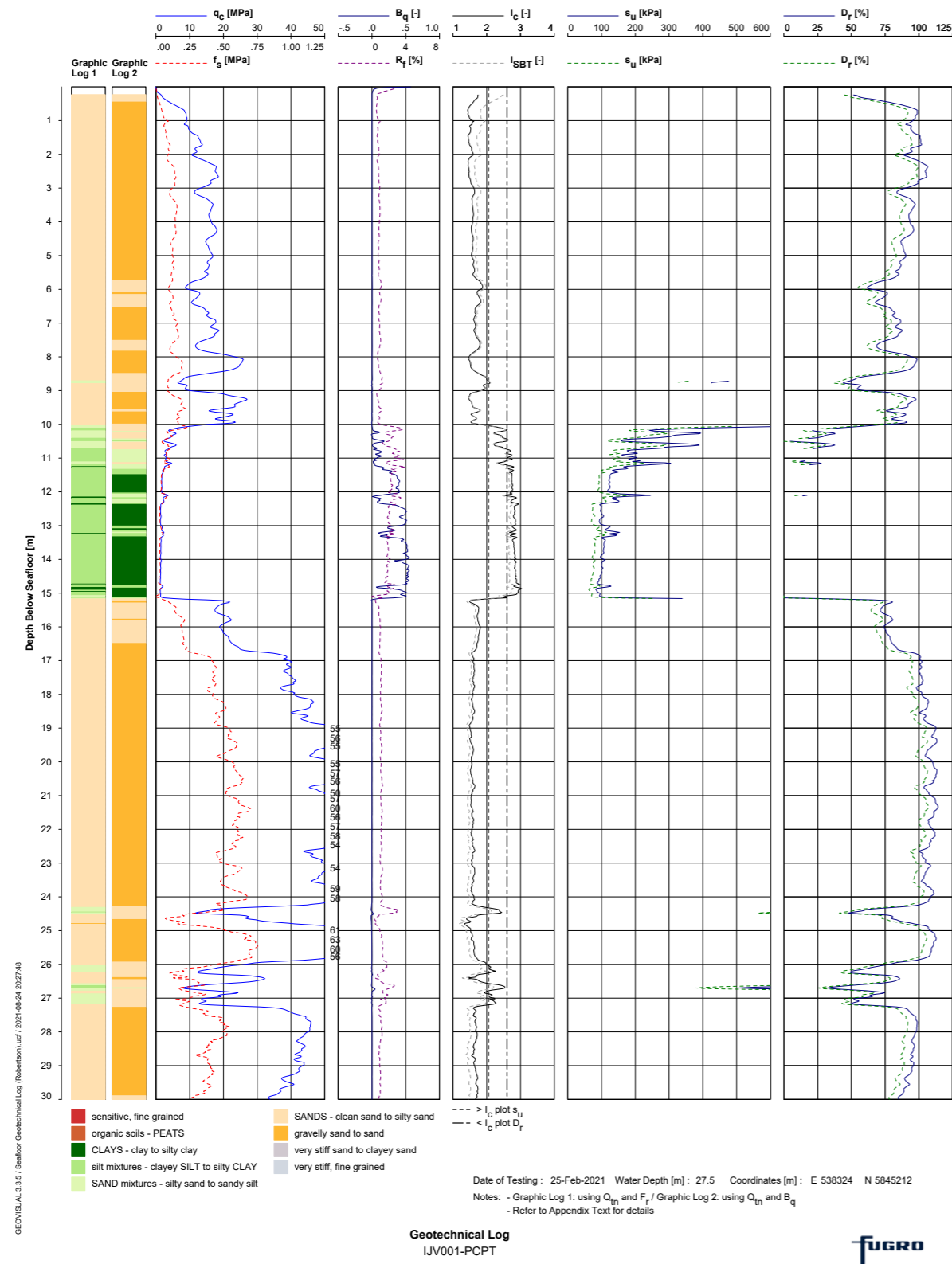


Figure 4.6.1 Geotechnical log presenting interpretation of soil profile and measured and derived parameters based on CPT results



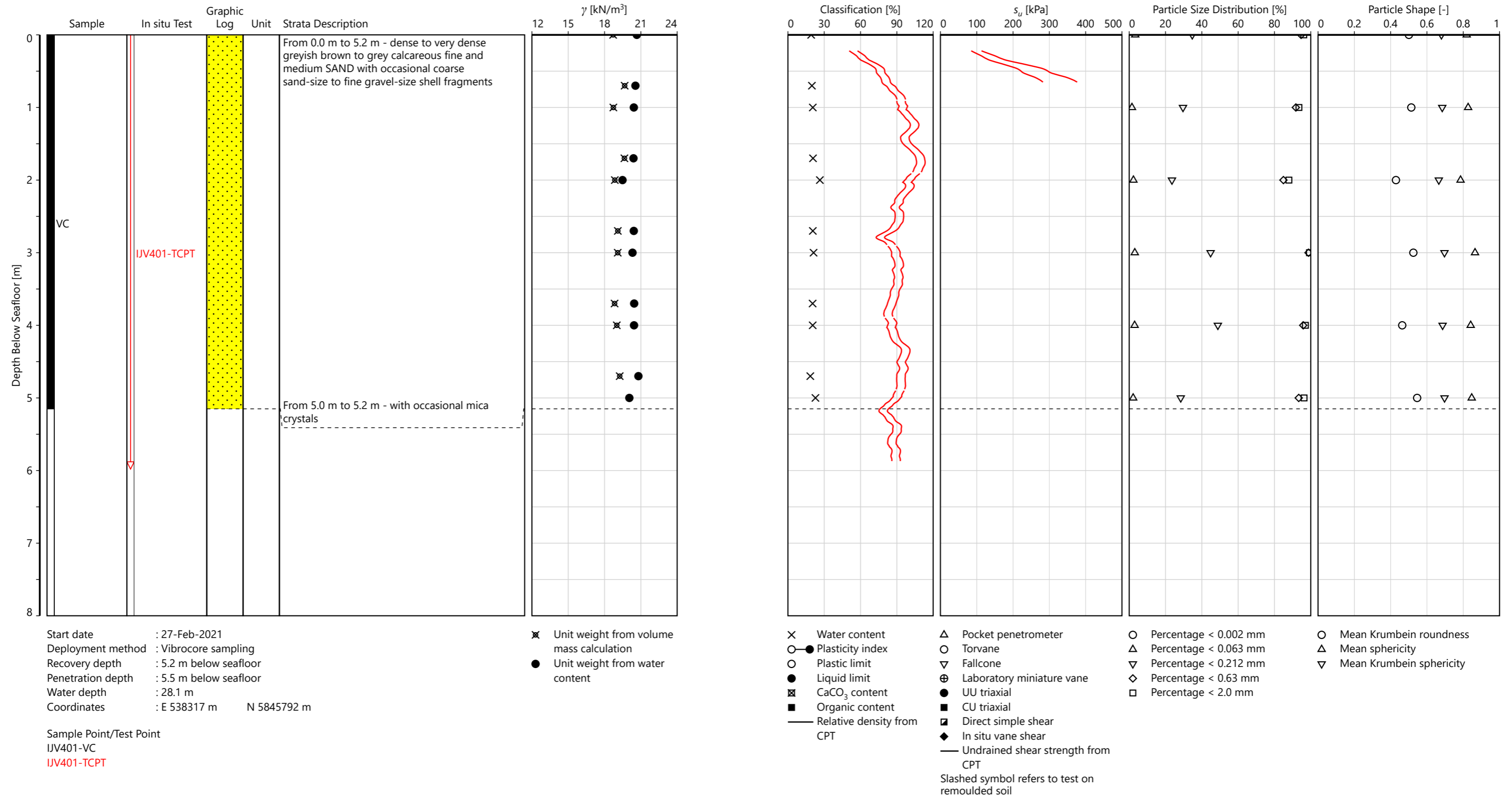


Figure 4.6.2 Geotechnical log presenting interpretation of soil profile, strata descriptions, measured and derived parameters based on in situ test data (TCPT), sampling and laboratory test results

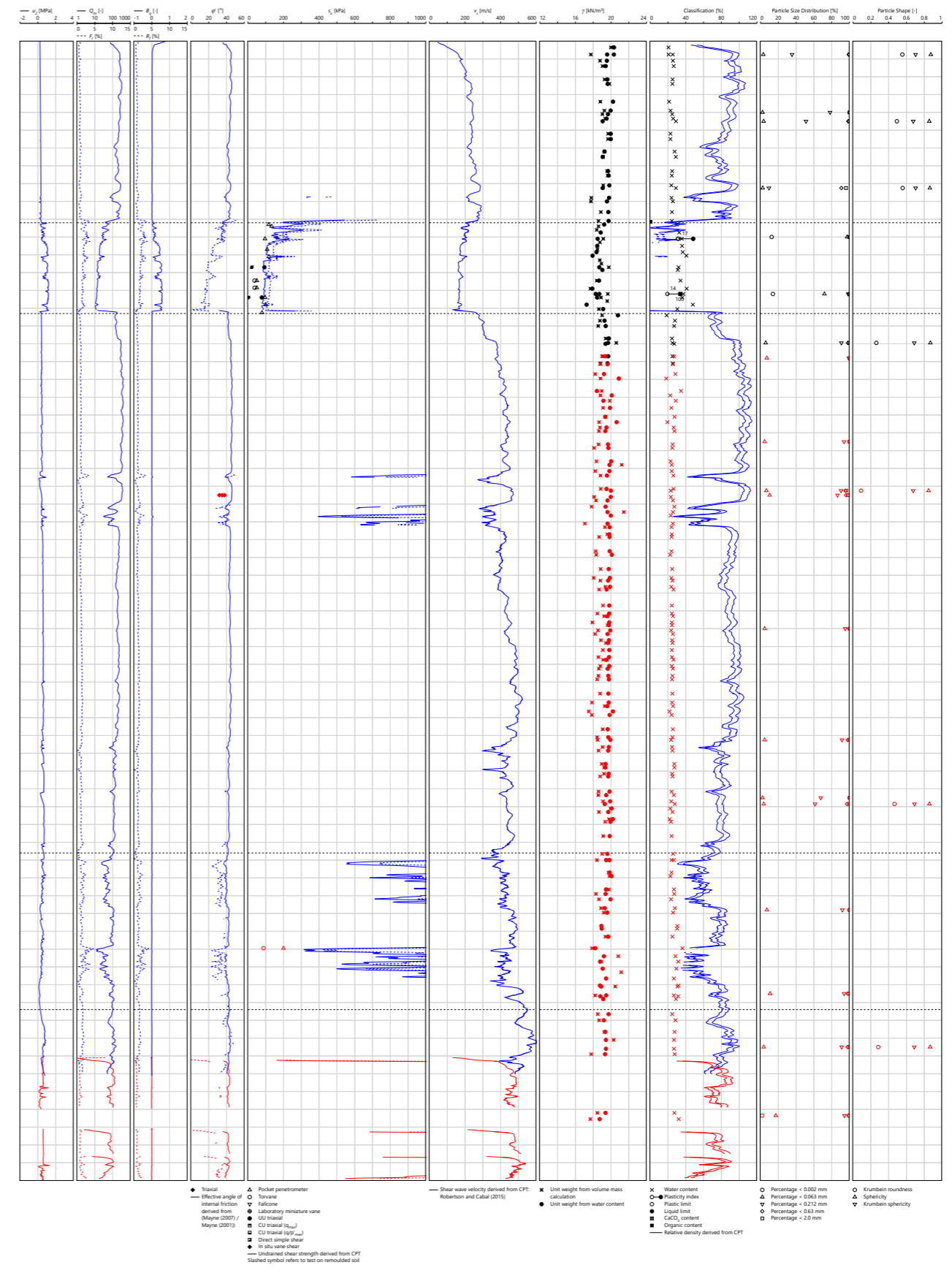
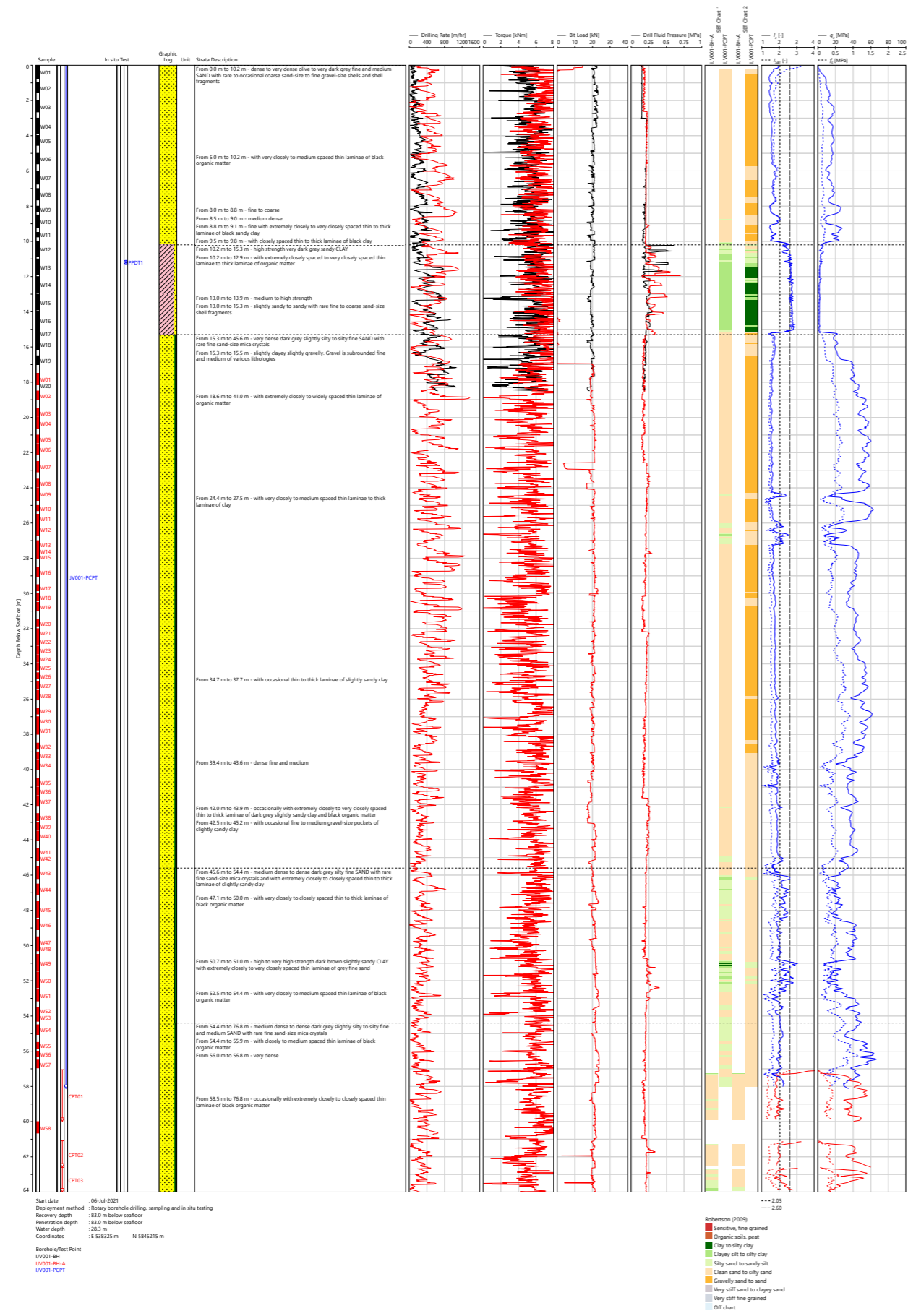
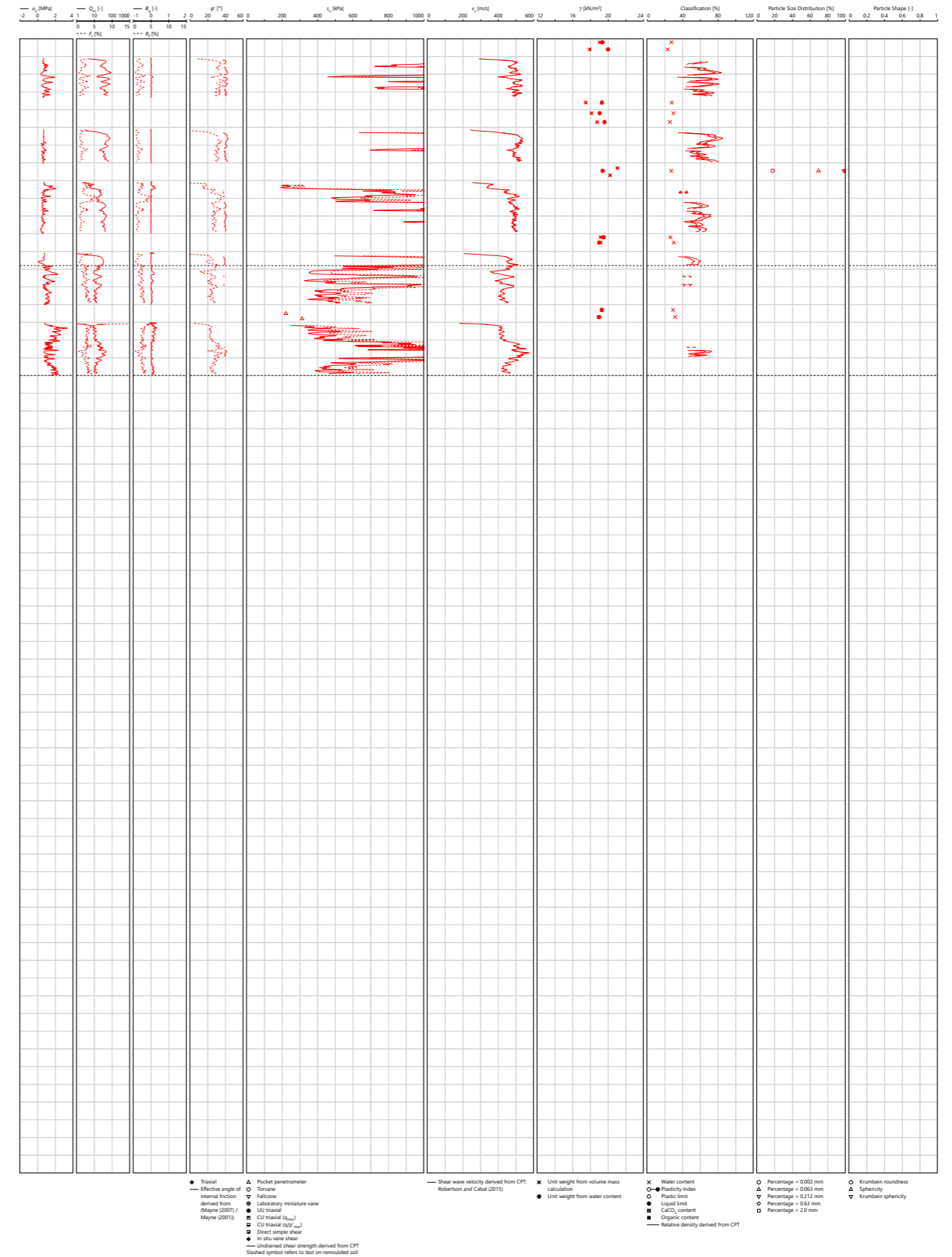
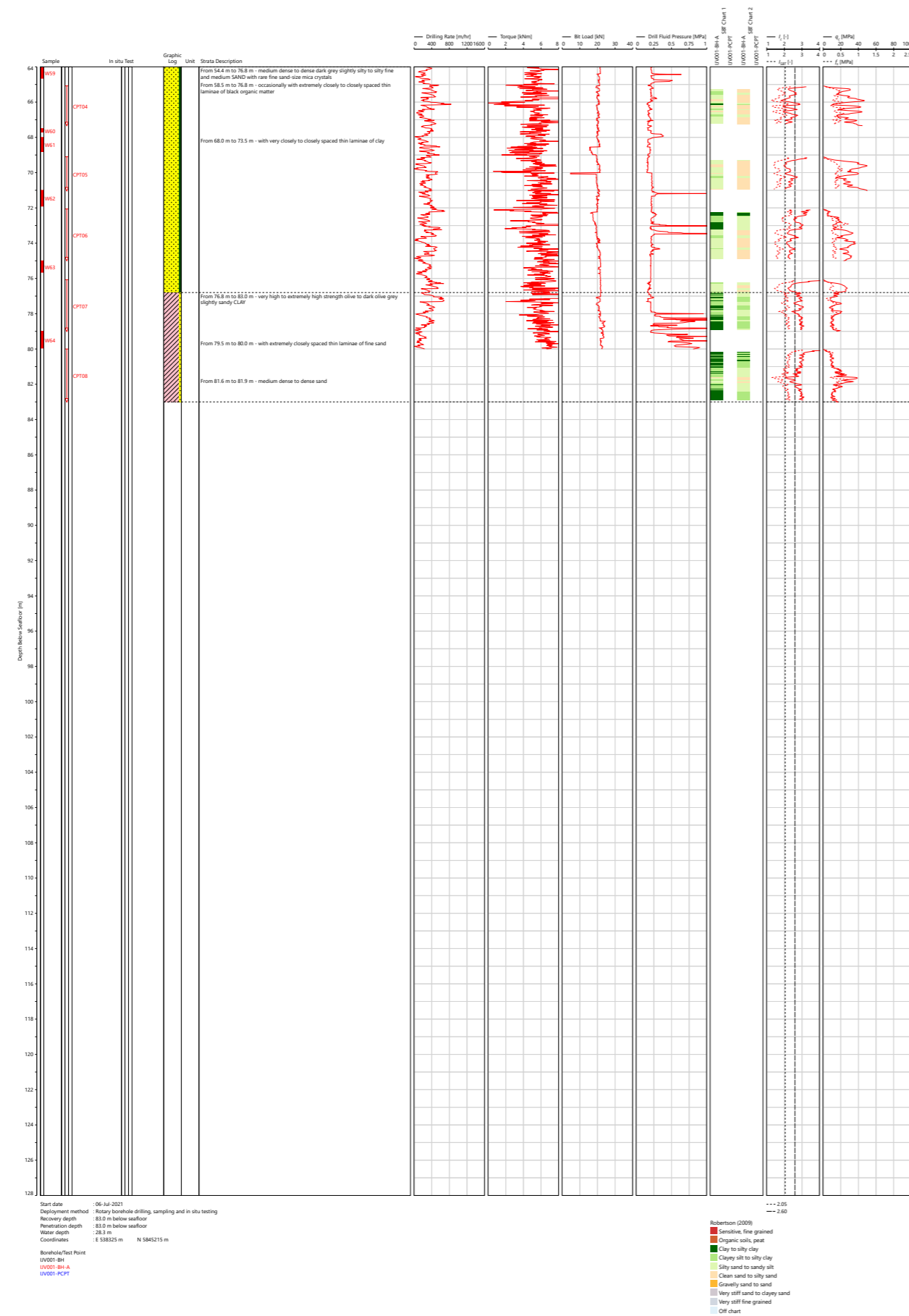


Figure 4.6.3 Geotechnical log presenting interpretation of soil profile, strata descriptions, measured and derived parameters based on in situ test data (records of drilling parameters, CPT, and SVT), sampling and laboratory test results



4.7 Archaeological assessment of paleo-landscapes

4.7.1 Aims

Following on from its initial work on the Archaeological desk study and Archaeological assessment of Geophysical data, Periplus Archeomare investigated the development of prehistoric landscapes in the IJWVFS Alpha and IJWVFS Beta in the North Sea through the analysis of vibrocore samples. Fugro carried out a Geotechnical site investigation to collect subbottom samples and data in IJWVFS Alpha and Beta. The overall goal of this assessment is to test the desk study-based expectancy for intact prehistoric landscapes and related archaeological remains in the area.

4.7.2 Objectives

The goals set for this assessment were:

1. To assess the geogenesis, occurrence, integrity, and preservation of prehistoric landscapes;
2. To 'dress' these landscapes, picturing the aquatic and terrestrial paleo-environments, through the analysis of microfossils, molluscs, pollen, diatoms and palynomorphs stored in the sediments.

4.7.3 Supplier

Periplus Archeomare was contracted by RVO to conduct an Archaeological assessment of paleo-landscapes. For this assessment, vibrocore samples were acquired by Fugro, which were analysed by BioChron.

4.7.4 Approach

This research primarily focuses on the vibrocore samples collected at 12 locations (see figure on the right). The samples taken at these locations have been designated for the assessment of paleo-landscapes. The samples were recovered from depths ranging from 3.5 mbsb to 6.1 mbsb. Samples were processed onboard and preserved for onward transport to the Fugro laboratory in Wallingford (UK).

4.7.5 Results

In the context of the development of the IJWVFS, a series of archaeological investigations was carried out. An Archaeological desk study showed that intact prehistoric landscapes and related prehistoric remains could occur in the area. To test and further specify this expectancy, a Geophysical survey was performed. Part of this survey was the deployment of shallow seismic to map the subsurface of the area. These seismic data was assessed to put the data in a geological context. The assessment pointed to the presence of intact late Pleistocene and Early Holocene landscapes in the area. The seismic data was used to specifically target locations where vibrocores could be sampled for specialist research.

The vibrocores were analysed and samples were taken for Optically Stimulated Luminescence (OSL) dating and radiocarbon (^{14}C) dating. These dating methods played a key role in the interpretation of the way prehistoric landscapes evolved in the Early Pleniglacial, Late Glacial and Early Holocene. From the assessment of the vibrocore data and the use of dating methods, the evolution of the landscape can be summarised as follows:

1. Towards the end of the Cromerian interglacial (465 ka ago), the IJWVFS was part of the delta of the Rhine and Meuse which transported gravel, sand and clay to the area.
2. During the following Elsterian glacial (465 - 418 ka ago), the polar ice sheets expanded resulting in a drastic drop in sea level. Glacier tongues migrated from north to south over the IJWVFS area. Underneath the glaciers, the Cromerian fluvial and deltaic deposits were abraded and deformed (thrust) by the moving ice sheet.
3. At the onset of the warm Holsteinian interglacial (418 ka - 386 ka ago), huge meltwater pathways developed underneath the retreating glaciers. The resulting deep tunnel valleys have been found in the IJWVFS Gamma.
4. In the course of the Holsteinian interglacial (418 ka - 386 ka ago) temperatures rose and precipitation increased. Mixed temperate forests with pine, alder and birch developed, which evolved into a more open landscape with pine, oak, boxwood, silver fir, heather and grasses towards the end of the Holsteinian. The sea level rose to the level we see to date. Depressions that had been formed by the Elsterian glaciers were filled in with fine-grained marine sands.
5. In the following period (386 ka - 130 ka ago), successive glacial and interglacial periods alternated. There are no clear indications that sedimentation took place in the area during these phases. Yet, local deposition could have taken place; for instance periglacial aeolian, fluvial or lacustrine sands during the Hoozeveen and Bantega interstadials (242 ka - 186 ka ago), or glaciofluvial sands originating from a melting glacier tongue (160 ka ago) that then was situated east of the IJWVFS.
6. During the Eemian interglacial period (130 ka - 115 ka ago), temperatures rose worldwide which led to a rapid rise in sea level. The area was inundated and open marine conditions developed. The glacial basins were filled with marine sands, with clay topping the Eemian sequence. Foraminiferal assemblages found in a metres-thick sequence of silty clay in the Brown Bank area (IJWVFS Alpha) have been deposited in the relatively deep subtidal marine environment (<30 m). The surrounding landscape was vegetated with pine forest, with occasional deciduous trees (birch, oak and alder), grasses, asters and carnation flowers, and peat moss in boggy areas.

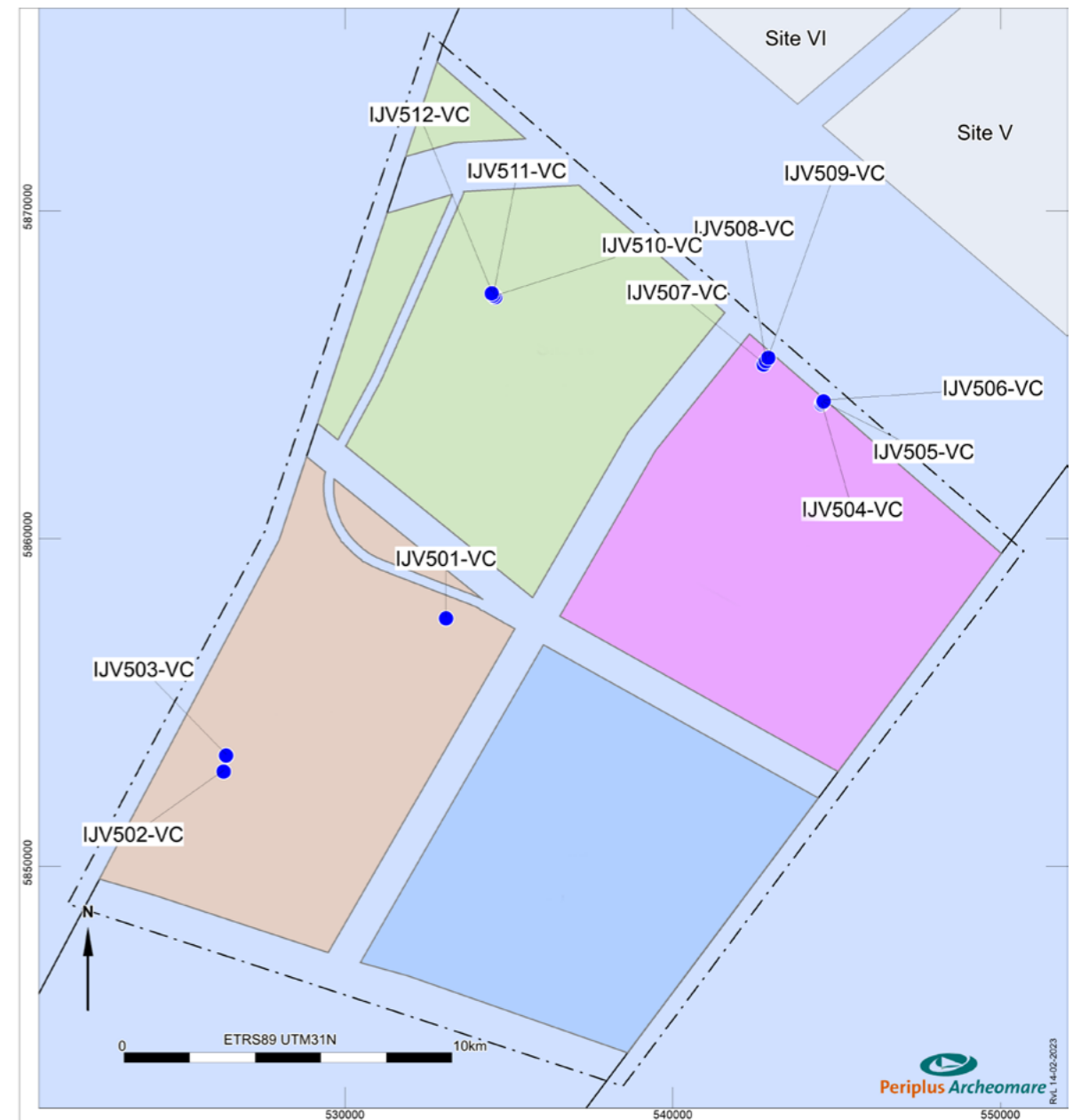


Figure 4.7.1 Borehole sample locations for geo-archaeological research

7. At the onset of the Weichselian glacial (115 ka ago), sea level dropped. Eemian marine beds of sand and clay became exposed at the surface. The outcropping clay beds were repined and became very stiff (as we find them today).
8. During the Early Glacial (130 ka - 74 ka ago), cold stadial climate phases with open treeless vegetation (Herning, Rederstall) alternated with temperate interstadials (Brørup, Odderade) during which boreal forests developed. Along with the temperature changes, sea level fluctuated. Due to its low surface elevation (around -35 m), the IJWVFS was very susceptible to those fluctuations. It is believed the area could have been inundated multiple times. During the Odderade interstadial

(85 ka - 74 ka ago), sea level rose above -20 m and marine sediments were likely deposited in the area.

9. At the end of the Odderade interstadial, temperatures dropped drastically. Renewed storage of fresh water in polar ice sheets led to a lowering of sea level below -50 m. The Odderade and older marine deposits became exposed at the surface. The channel belt of the Rhine expanded westward. Initially, the river had a meandering character. The climate continued to cool during the Early Pleniglacial (74 ka - 59 ka ago). Large seasonal fluctuations in the discharge of meltwater and suspended sediments led to the development of a braided river system with deeply incised channels amidst a perma-

frost landscape. The imprints of this northwest-trending braided river are reflected by the pronounced morphologic characteristics of the base of seismic unit B. The northeastern part of IJWFS Beta form the landscape bordering the Early Pleniglacial channel belt of the Rhine, 68 ka ago. Marine molluscs and microfossils including foraminifera, ostracods and diatoms are reworked from older marine strata into the river deposits.

10. During the Middle Pleniglacial (59 ka - 30 ka ago), the Rhine channel belt shifted southward and abandoned the IJWFS. During the remainder of the Middle and Late Pleniglacial (59 ka - 15 ka ago), including the extremely cold Last Glacial Maximum (LGM, 21 ka ago), no large-scale (fluvial) deposition took place, albeit that wind action could have led to deflation and development of desert pavements, and even soils could have formed during the Hengelo interstadial (39 ka - 38 ka ago) and Denekamp interstadial (28 ka - 32 ka ago). Possibly, the paleosol at the top of the lower part of seismic unit C (Site III; IJV504-VC; 5.46 m to 5.80 m) formed during one of these periods.
11. After the extreme cold LGM, the climate improved. Still, during this Late Glacial stage (15 ka - 12 ka ago), climatic fluctuations occurred. In the IJWFS, small streams developed during the relatively warm Bølling (14.6 ka - 14.0 ka ago) and Allerød interstadials (13.9 ka - 12.9 ka ago). A meandering beak in IJWFS Beta developed and was filled in with laminated and layered clayey and fine sandy sediments. At the location of vibrocore IJV506-VC in Site III this sedimentation took place around 14.1 ± 0.8 ka (OSL), while radiocarbon-dated plant material puts an upper limit on this age of 13.8 ± 0.2 cal. ka BP.
12. Due to the warming climate during the Holocene (12 ka ago - present) sea level rose from -50 m at the end of the Late Glacial (12 ka ago) to -32.0 m LAT | -32.8 m MSL some 10 ka ago (Boreal stage 10.3 ka - 8.7 cal ka BP). The rise of sea level resulted in the freshwater groundwater rising as well. Within the stream valley area of IJWFS Alpha and IJWFS Beta, peat was deposited in shallow fresh to brackish water bogs with bullrush.
13. The ongoing Holocene sea level rise transformed the area into a brackish water tidal lagoon. Abundant *Peringia* ulvae, characteristic of the Velsen Bed, are found, which proves that these sediments indeed reflect the earliest Holocene clastic sedimentation in the area.

14. During the later stages of the Holocene, tidal current led to the deposition of sand and the formation of sand ridges and sand dunes on top of the older paleo-landscapes.

The objective of this study to assess the evolution of paleo-landscapes has been met. The conclusion that the Early Pleniglacial channel belt of the Rhine extended over almost the entire IJWFS has not been documented before. To date, this fast sequence of subcropping sands have been classified as the Early Holocene marine deposits of the Wormer Member/Naaldwijk Formation. We suggest classifying these sands as the Kreftenheye Formation instead.

This was the last phase in the process of archaeological research for the IJWFS. No additional archaeological research is advised. Future seabed disturbing activities in the area, like installation of foundations and interconnecting cables, are not affected by the outcome of this study and can continue as planned. However, if additional geophysical or geotechnical surveys are carried out, for instance in the course of cable lay activities, the resulting data is requested to be delivered to the competent authorities. These data include newly collected seismic data, borehole and vibrocore samples, which are made available by RVO to scientists for use in their scientific research.

Finally, during the installation of the wind turbines and cable lay operations, archaeological objects may be discovered which were completely buried or not recognised as an archaeological object during the Geophysical survey. Periplus Archeomare recommends archaeological supervision based on an approved Programme of Requirements. Implementing this recommendation would prevent delays during the work when unexpected archaeological remains are found. In accordance with the Heritage Act (Erfgoedwet), those findings must be reported to the competent authority. This notification must also be included in the scope of work.



4.8 Ground Model

4.8.1 Overview

An integrated ground model (IGM) is available for input in design, operation and decommissioning of wind farm assets at IJVVFS Alpha and IJVVFS Beta. The ground model covers geological setting, geohazards and geotechnical soil parameters. The IGM provides a state of knowledge document and digital deliverables relating to the geotechnical site conditions for wind farm development in the two IJVVFS sites. The IGM includes:

- Evolutionary geological setting for the sites incorporating geochronological test results;
- Presentation of geophysical units and seismostratigraphy (Figure 4.8.1);
- Summary of soil units for the sites (Table 4.8.1);
- Integration of geophysical units and soil units for the sites to develop soil province maps to a depth of 60 m BSF (Figure 4.8.2);
- Geo-risk register;
- A 3D geological model to provide insight into the soil characterisation (Figure 4.8.3);
- Compilation of geodata and assessment in GIS formats.

Additional to the IGM report, a Geotechnical Interpretative Report (GIR) is available. The purpose of the GIR is to provide information suitable for progressing the design and installation requirements for offshore structures at IJVVFS Alpha and IJVVFS Beta. The GIR includes:

- Geotechnical ground model, including soil provinces and soil units (geotechnical);
- Synthetic profiles of cone penetration test (CPT) net cone resistance (qn) (Figure 4.8.4) and shear modulus at small strain (Gmax);
- Geotechnical parameters (Table 4.8.1);
- Seismic hazard assessment;
- Recommendations for microbially influenced corrosion of steel in soil.

4.8.2 Supplier

The IGM and GIR were provided by Fugro. Fugro is committed to sustainability and participant in the United Nations Global Compact.

4.8.3 Results

Integrated Ground Model

The IGM at the IJVV Ground Model Investigation Area is the result of iterative integration techniques using a wide range of datasets and processes. The key datasets used to derive the IGM are:

- In-situ geotechnical data;
- Bathymetric and seabed mapping;
- Reprocessed seismic interpretation;
- Bespoke velocity model for 2D UHR seismic reflection data.

The key findings for the IGM are as follows:

Bathymetry

Water depths typically range between 20 m and 45 m and are deepest towards the southwest. The seafloor morphology is dominated by sand waves and north-south trending sand banks. Seafloor slope angles typically are less than 5°. However, raised slope angles are locally present in relation to the seafloor morphology.

Geology

Interpretation of reprocessed seismic reflection data and geological data revealed a stratigraphic succession of sands and clays, dated to have been deposited from the Pleistocene to the Holocene.

Detailed geotechnical and seismostratigraphic unitisation was carried out following integration of over 400 reprocessed 2D UHR lines and 700 geotechnical locations and a dedicated seismostratigraphic framework was developed.

Eight seismostratigraphic units were identified and correlated to eight unique geotechnical soil units.

Table 4.8.1 Summary of soil conditions and derived seismostratigraphic and geotechnical soil units

Geological Age	Geological Name	Depositional Environment	Seismo-stratigraphic Unit	Geotechnical Soil Unit	Lithological Description
Holocene	Bligh Bank Formation	Marine	A	GT1	Fine and medium SAND
	Holocene Channels (undifferentiated)	Coastal to tidal channel infill deposit	B*	GT2c	Fine and medium SAND and sandy CLAY or SILT
Holocene (Naaldwijk)	Naaldwijk Formation	Coastal to tidal flat, lagoonal and glaciofluvial	B	GT2	Fine and medium SAND
Late Pleistocene (Weichselian – Eemian)	Eem Brown Bank Member	Shallow marine to lagoonal	C	GT3	Clayey silty SAND and sandy CLAY or SILT
Late Pleistocene (Eemian)	Eem Sand Member	Shallow to open marine	D-1	GT4	Fine and medium SAND
	Eem Clay Member	Shallow marine to lagoonal	D-2	GT5	Slightly sandy or slightly gravelly CLAY or SILT
	Transitional Soil Member	Shallow marine sheet deposit with local channel infill	D*	GT5*	Fine and medium SAND
Middle Pleistocene (Cromerian)	Yarmouth Roads Formation	Shallow marine to lagoonal and fluvial	E	GT6	Silty fine and medium SAND and CLAY or SILT

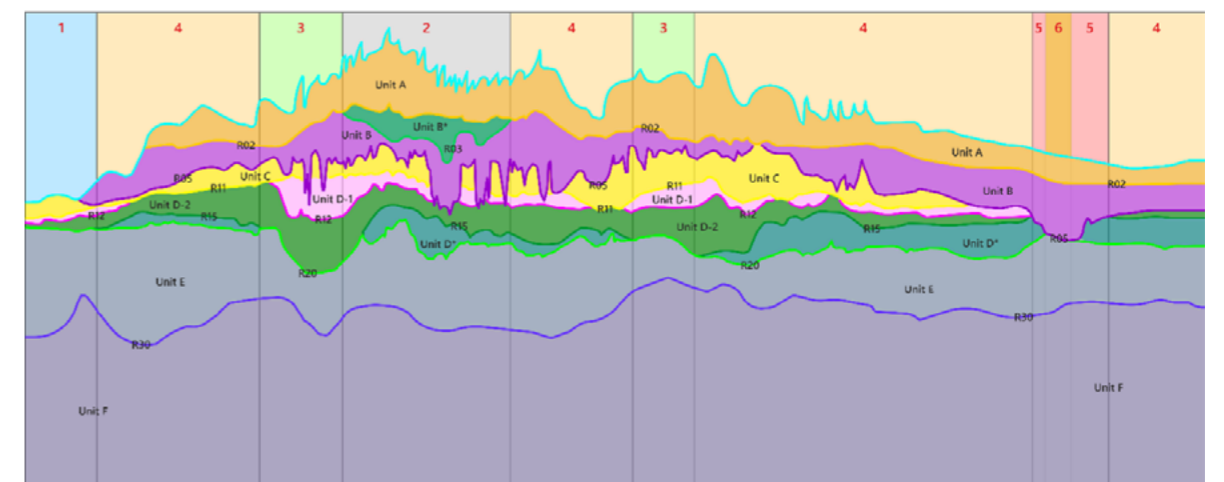


Figure 4.8.1 Conceptual cross section (not to scale) of soil stratigraphy showing soil units A to F and key engineering provinces (1 to 6); blue line represents seafloor

Soil Provinces

Ground conditions can be broadly characterised by six soil provinces and profiles, which group together areas of similar geotechnical properties (Figure 4.8.1, Figure 4.8.2, Table 4.8.1);

- **Soil Province 1** occurs where the Yarmouth Roads Formation (Seismostratigraphic Unit E/F) is present close to the seafloor, typically within 5 m BSF. Overlying sediments in this province are expected to be present as thin layers;
- **Soil Province 2** is present where Holocene (undifferentiated) Channels are present within the soil profile, related to the extent of Seismostratigraphic Unit B*. All of the seismostratigraphic units identified across the sites may be present in Soil Province 2; however, they are expected to be eroded, incised or modified by the Holocene channel systems;
- **Soil Province 3** occurs where all seismostratigraphic units are present, with the exception of the Holocene channels (Seismostratigraphic Unit B*) and the Transitional Soil Member (Seismostratigraphic Unit D*). This soil province contains a sequence of clayey sediments in the profile (Seismostratigraphic Units C and D-2);

- **Soil Province 4** occurs where all soil units are present, with the exception of the Holocene (undifferentiated) Channels. This province contains at least one clay dominated seismostratigraphic unit and includes the Transitional Soil Member (Seismostratigraphic Unit D*);
- **Soil Province 5** occurs on the flanks of channels of the Naaldwijk Formation. There are only sand lithologies present in the resultant soil profile (Seismostratigraphic Units A, B, D* and E/F). The presence of the Transitional Soil Member (Seismostratigraphic Unit D*) defines soil province;
- **Soil Province 6** occurs where there is deeper channelisation of the Naaldwijk Formation into the deeper Yarmouth Roads Formation. This results in a profile that is mostly sand and includes Seismostratigraphic Units A, B and E/F. The sands of Seismostratigraphic Units D-1 and D* and the clays of Seismostratigraphic Units C and D-2 are absent due to the incision of the Naaldwijk Formation within this soil province.

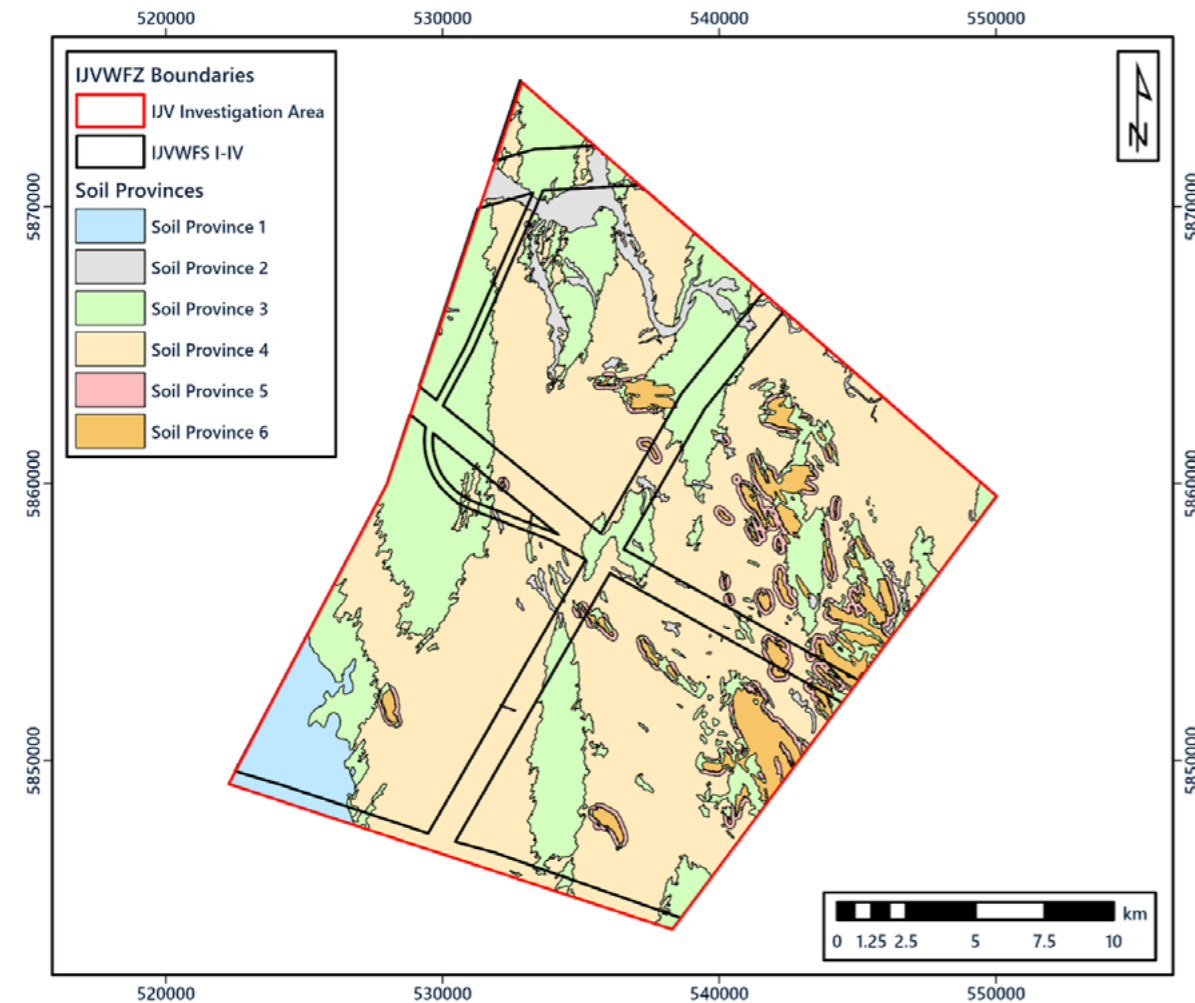


Figure 4.8.2 Soil province map derived across the IJWFS Investigation Area

Geotechnical Interpretative Report

The GIR presents the geotechnical ground model, which effectively builds on the geological ground model by considering soil provinces and key soil units (Table 4.8.2) that are important for WTG foundation design. The geotechnical ground model includes detailed summaries and statistical analyses of geotechnical parameter values (Table 4.8.3).

For conceptual foundation design of offshore wind turbines at IJWFS I-IV, the extent of available information and quality of data meets or exceeds the requirements of IEC 61400-3-1:2019, ISO 19901-8:2014 and ISO 19901-10:2021.

Digital Deliverables

The IGM and GIR reports are accompanied with digital deliverables.

GIS (2D) Digital Data

An ESRI ArcGIS project hosts digital ground model elements of the IGM and GIR, including:

- Geotechnical (seabed) investigation locations - comprised of seabed CPT (including seismic CPT and temperature CPT) and vibrocore;
- Geotechnical (downhole) investigation locations – comprised of boreholes;
- Bathymetric data;
- Seabed infrastructure;
- Depth to all mapped geophysical horizons;
- Soil province map.

Table 4.8.2 Soil units per soil province

Soil Province	Proportion of IJWFS I-IV [%]	Soil Unit								Primary Feature/Comments
		GT1	GT2	GT2c	GT3	GT4	GT5	GT5*	GT6	
1	4	(✓)	(✓)	✗	(✓)	(✓)	(✓)	(✓)	(✓)	Top of GT6 at < 5 m BSF
2	4	(✓)	(✓)	✓	(✓)	(✓)	(✓)	(✓)	(✓)	Presence of GT2c
3	27	(✓)	(✓)	✗	(✓)	(✓)	(✓)	✗	(✓)	Presence of GT3 and/or GT5
4	55	(✓)	(✓)	✗	(✓)	(✓)	(✓)	✓	(✓)	Presence of GT3 and/or GT5 and GT5*
5	6	(✓)	✓	✗	✗	(✓)	✗	✓	✓	Presence of GT2 and GT5*
6	4	(✓)	✓	✗	✗	✗	✗	✗	✓	Presence of GT2

Notes:

- 'Proportion' refers to the plan area of each soil province with respect to the plan area of the site
- denotes distinguishing soil unit(s) key for governing structure design for the particular soil province
- ✓ denotes presence of soil unit within soil province
- () denotes partial presence of soil unit within soil province within the depth range of 0 m to 50 m BSF
- ✗ denotes absence of soil unit within soil province

Kingdom (2D) Digital Data

An IHS Kingdom Project hosts geophysical data and geotechnical used in the IGM and GIR. Within this dataset the user will be able to access and view:

- All seismic reflection SEG-Y files in depth and time domain;
- Geophysical interpretation of the seismostratigraphic unit boundaries;
- Geophysical interpretation of anomalies and features of interest;
- Geotechnical investigation locations and CPT profiles.

3D Ground Model

A 3D ground model (Figure 4.8.3) is hosted in Leapfrog Viewer. It presents an interpolative 3D ground model of seismostratigraphic soil conditions, integrated with geotechnical profile data for the whole of IJWFS I-IV and also for each individual Wind Farm Site to ensure data resolution that is appropriate for the model.

The Leapfrog Viewer model contains:

- Bathymetric surfaces;
- 3D seismostratigraphic model;
- Borehole and CPT locations and their unitisation;
- Seven cross sections.

Synthetic Parameter Profiles

Synthetic parameter profiles (net cone resistance and shear modulus at small strain, Figure 4.8.4) are available for along the geophysical survey track lines across IJWFS I-IV at a horizontal spacing of about 1 m. These digital profiles can be viewed in any software that can read SEG-Y files.

4.8.4 Webinar

The results of the IGM and GIR were discussed at a webinar on 15 June 2023.

Please refer to offshorewind.rvo.nl/ for details.

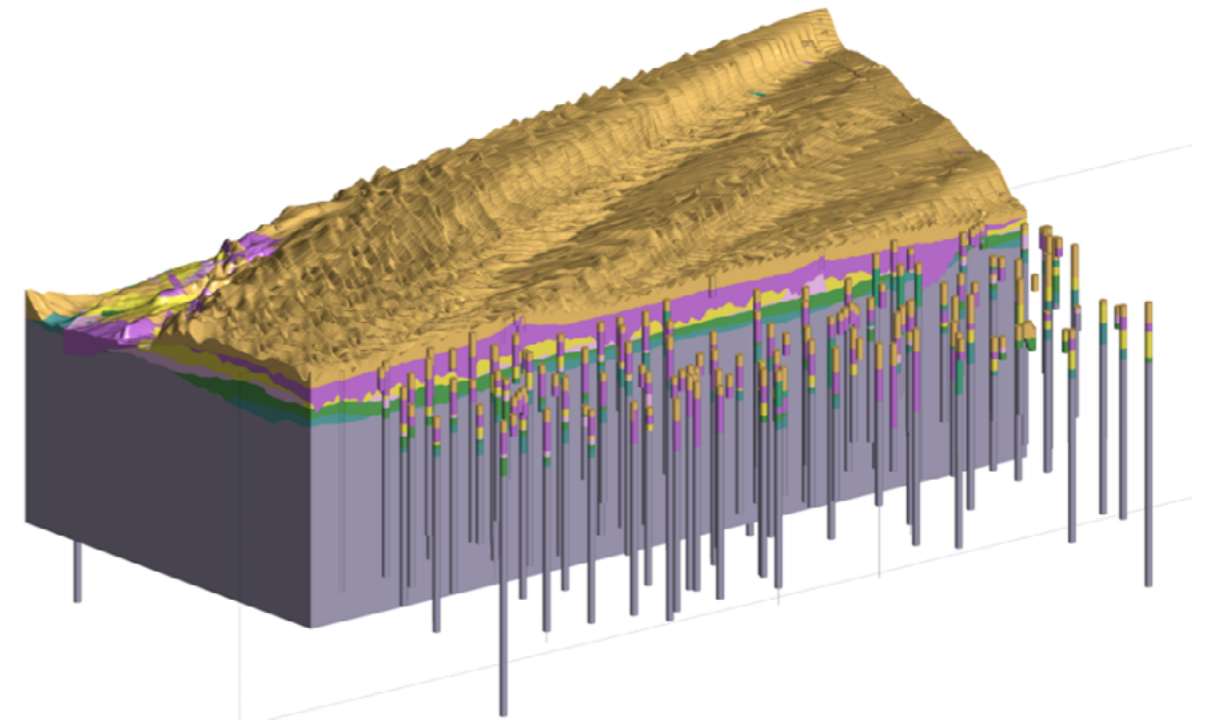


Figure 4.8.3 3D ground model of soil conditions, hosted in Leapfrog Viewer, vertical stick logs illustrate soil units at geotechnical investigation locations

Table 4.8.3 List of geotechnical parameters derived in GIR

Geotechnical Parameter	Symbol	Parameter Values		
		Soil Type		
		Sand	Transitional	Clay
Net cone resistance	q_n	✓	✓	✓
Soil unit weight	γ	✓	✓	✓
Minimum and maximum index void ratios	$e_{min} e_{max}$	✓	-	-
Relative density	D_r	✓	-	-
Yield stress ratio	YSR	✓	✓	✓
Coefficient of earth pressure at rest	K_0	✓	✓	✓
Constrained modulus	M	-	-	✓
Undrained shear strength in triaxial compression (TXC)	$s_{u,TXC}$	✓	✓	✓
Undrained shear strength in direct simple shear (DSS)	$s_{u,DSS}$	✓	✓	✓
Peak effective angle of internal friction	ϕ'	✓	✓	-
Effective angle of internal friction at large strain	ϕ'_{cv}	✓	✓	-
Angle of dilatancy	ψ	✓	✓	-
Angle of interface friction – steel/soil	δ	✓	✓	✓
Coefficient of permeability	k	✓	✓	-
Shear modulus at small strain	G_{max}	✓	✓	✓
Normalised shear modulus	G/G_{max}	✓	✓	✓

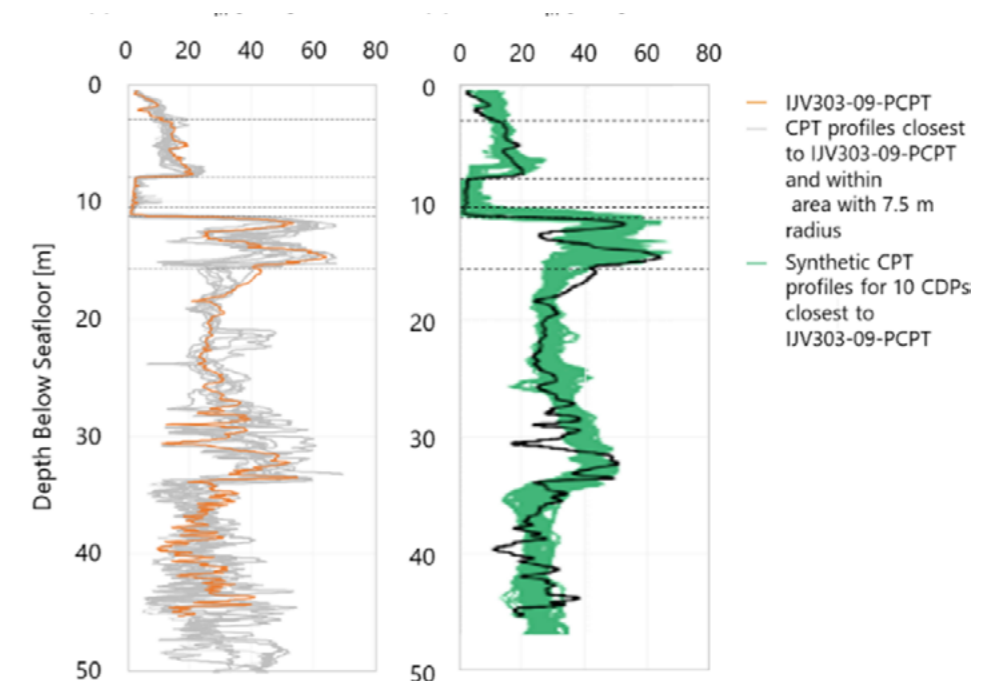


Figure 4.8.4 (a) Cone penetration test (CPT) profiles for nested location cluster IJV303 with profiles spaced at about 5 m horizontal distance; (b) Synthetic CPT profiles (green) for 10 locations spaced at about 1 m closest to IJV303-09-PCPT (black); synthetic CPT

4.9 Morphodynamics and Scour Mitigation assessment

4.9.1 Study Overview

This desk study comprises two parts: i) site morphodynamics and ii) scour mitigation. The assessment of site morphodynamics addresses autonomous seabed dynamics in the entire IJVVWFZ. The second part provides general considerations on how to deal with scour development and scour mitigation in IJVVWFZ, taking into account the morphodynamics of the area and a range of potential foundation types. In addition, general considerations for cable routing in a morphodynamically active environment are provided. The analysis utilises and relies upon existing historical data and newly acquired data collected during recent site-specific surveys commissioned by RVO.

The aim of this combined study was to:

1. Assess site morphodynamics and characterise the seabed at IJVVWFZ;
2. Characterise the shallow geological and sedimentological site conditions to a depth of 20 m below the measured seabed level as well as the seabed features at the IJVVWFZ;
3. Predict the change in seabed levels at IJ over the lifetime of a wind farm (considered period: 2020 – 2072) to support the design, installation and maintenance of wind turbines, inter array cables, platforms and their support structures.
4. Provide guidance on the depths at which UXOs may be encountered, based on a hindcast of historic seabed levels (1945-2022);
5. Describe scour conditions that may be expected at IJVVWFZ for typical wind farm-related structures;
6. Provide a state-of-the-art overview of scour mitigation measures and their applicability at IJVVWFZ for various foundation types;
7. Provide guidance on how the site morphodynamics could be accounted for in the selection and design of wind farm infrastructure, cable routing and scour mitigation strategies.

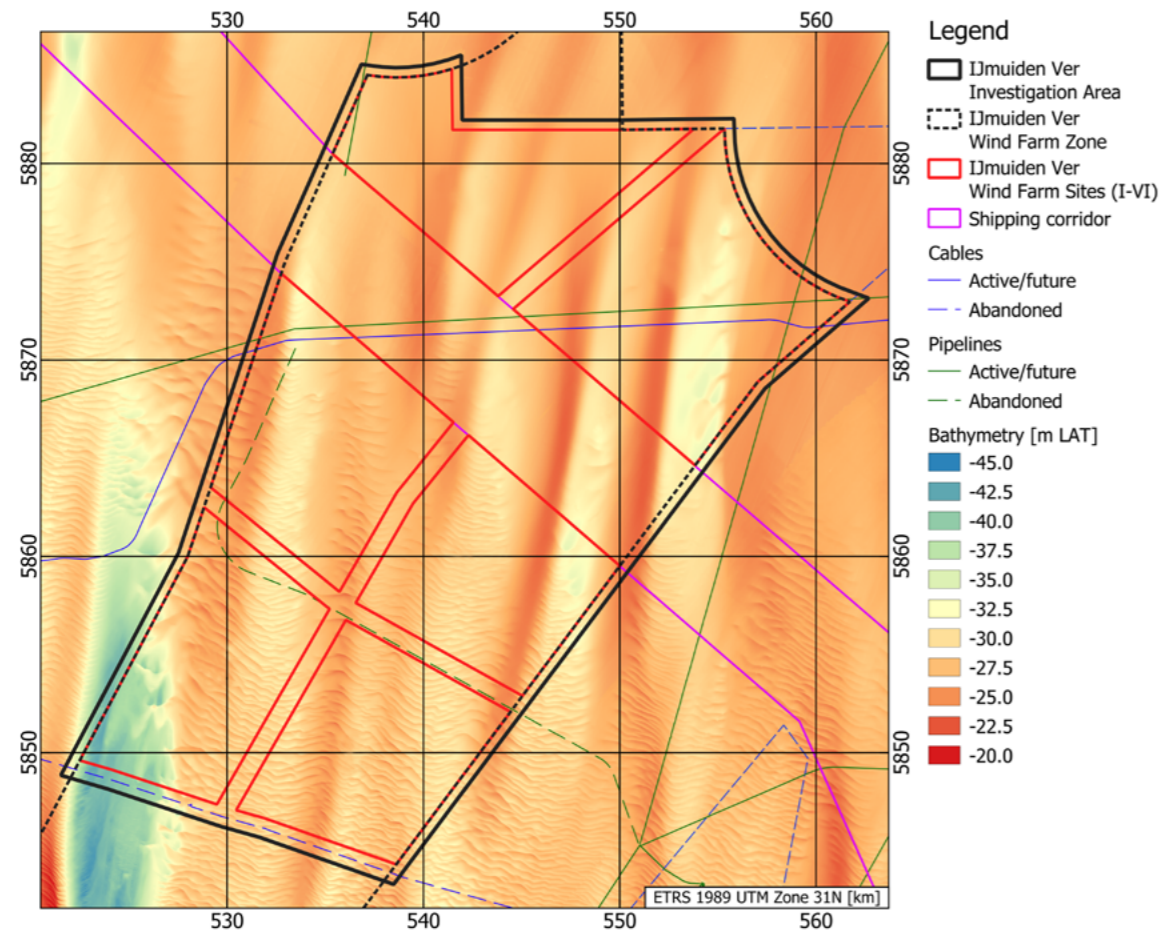


Figure 4.9.1 Map view of the IJVVWFZ bathymetry as measured during the most recent surveys

The information presented should provide prospective developers with a detailed understanding of site morphodynamics and scour risk suitable to assist with the design, installation and maintenance of wind turbines, inter-array cables, substations and their support structures.

In recent years, methods and tools have been improved through the past morphodynamic and scour studies in the area. These improvements have been incorporated in the present study. Compared to Hollandse Kust (west) and Ten noorden van de Waddeneilanden, the analysis was extended with probabilistic ranges in historic trends, new methods for extrapolation of seabed levels, updated cable routing methodology and the inclusion of the impact of an extreme event on the seabed based on hydrodynamic and wave modelling. For scour mitigation strategies, more emphasis and detail is given to eco-friendly scour protections.

4.9.2 Supplier

Research institute Deltares was awarded the contract by RVO to conduct this desk study for the IJVVWFZ. Deltares has considerable experience in these types of studies having previously conducted morphodynamic studies for other offshore wind farms in the Dutch North Sea region, including Hollandse Kust (west, noord and zuid), Ten noorden van de Waddeneilanden, and Borssele, and various wind farm sites in the wider North Sea, Irish Sea, US East Coast, Taiwan Strait and the Baltic Sea. In addition, Deltares has performed scour assessments, developed scour mitigation strategies and executed physical model testing campaigns for many offshore wind farm sites in the North Sea, Irish Sea, US East Coast, Taiwan Strait and the Baltic Sea and for various TenNE platforms in the Dutch and German North Sea.

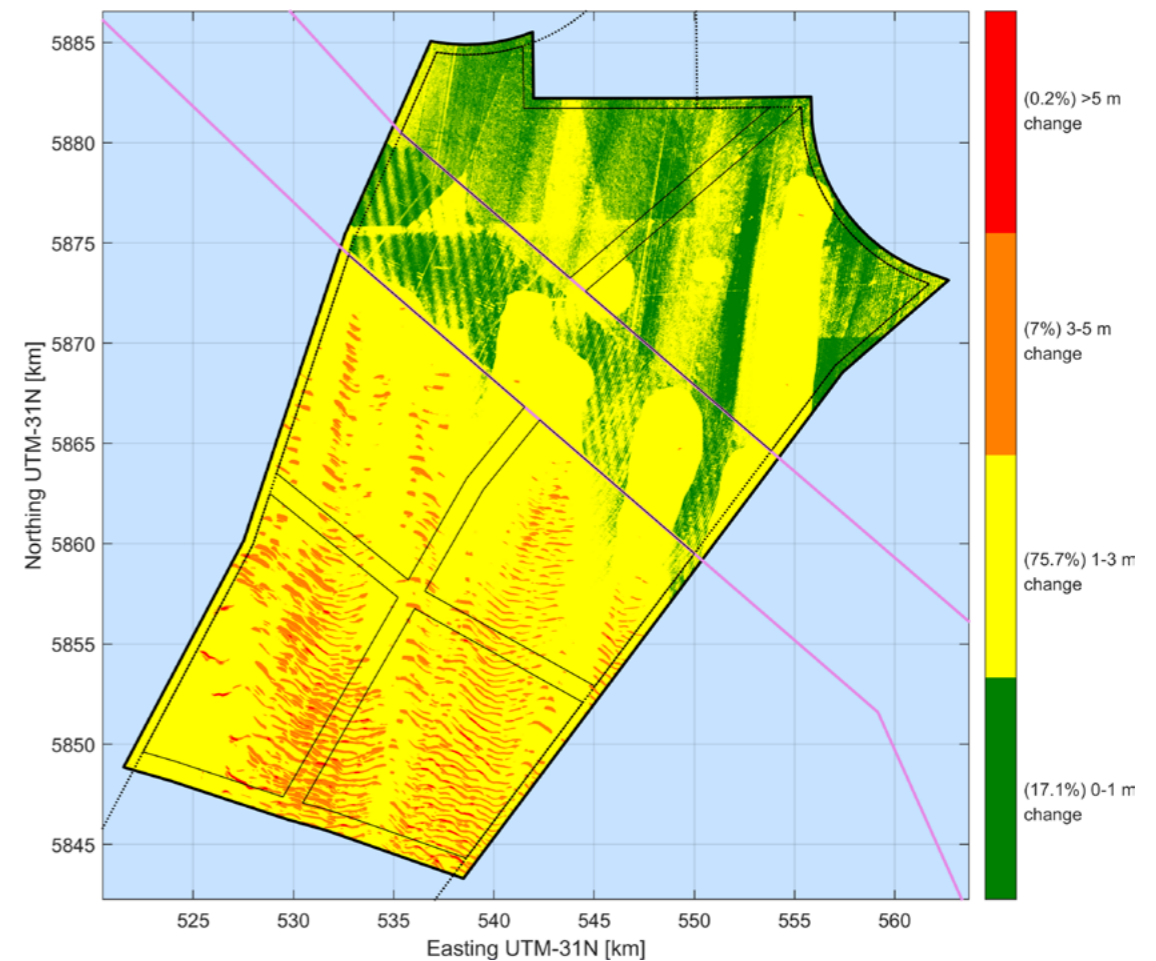


Figure 4.9.2 Classification of seabed level changes (in metres) that have been predicted

4.9.3 Results of the Morphodynamic assessment

The bathymetry in IJWWFZ has a non-uniform morphology including several prominent sand banks influencing sand wave dynamics. Sand waves, with megaripples on top, are found in IJWWFS Alpha and IJWWFS Beta. These features display a pronounced asymmetry towards the north-northeast indicating migration in that direction (Figure bathymetry). The seabed in IJWWFS Gamma is almost entirely devoid of sand waves and megaripples.

Considering the entire IJWWFZ the sand waves have wavelengths in the range of 170 to 620 m, heights of 0.9 to 3.5 m and migration speeds up to 2.7 m/year with a median speed of 1.6 m/year. Locally, sand waves are higher in IJWWFS Alpha and longer in Site Gamma (although here only a few sand waves are found). Spatial variability in migration rates and directions are assumed to be attributable to the presence of sand banks. On the western slope of the sand bank migration rates are highest, whereas sand waves on the eastern slopes are migrating at a slower rate. An analysis of the large-scale seabed variations shows that the underlying seabed may be considered broadly static over the lifetime of the wind farm.

geological and geophysical data indicates that non-erodible layers exist, but that they are located too deep to influence the sand wave migration. A numerical analysis of the prevailing hydrodynamic and sediment transport regime in the area indicated that the net sediment transport is aligned with the residual tidal flow and is directed towards the north-northeast. Directions of transport generally agree with the observed migration direction of sand waves. Simulation of storms with a return period of 50 and 100 years demonstrated that the impact of extreme events on the seabed across IJWWFZ is limited and that sediment transport is mostly tidally driven.

Based on the morphodynamic analysis, the Best Estimate Bathymetry (BEB), predicted lowest seabed level (LSBL) and predicted highest seabed level (HSBL) were determined for different timesteps across the lifetime of the wind farm. The LSBL and HSBL indicate, respectively, the lowest and highest seabed levels that are predicted to occur during the lifetime of the wind farm (2020-2072). These seabed levels include a spatially and temporally varying uncertainty analysis. Finally, classification zones were provided grouping predicted seabed level changes to several classes (See Figure 4.9.2).

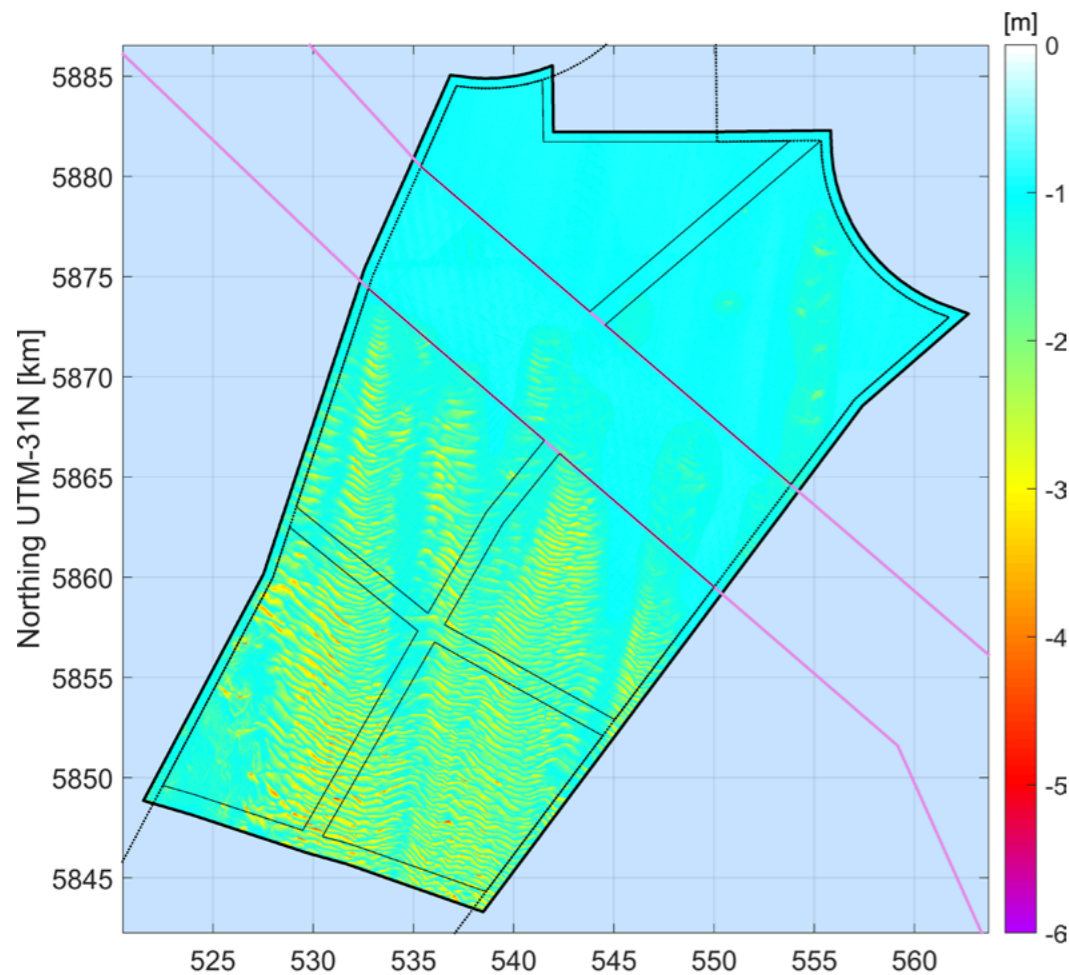


Figure 4.9.3 Predicted seabed lowering (in metres) over the period 2020 to 2072 including uncertainties

Comparison of the LSBL with the most recent measured bathymetry from 2020-2022 shows a predicted maximum local seabed level lowering of approximately -3.6 m as the 99.9%-non exceedance value. As expected, the largest lowering is found at the location of the existing sand wave crests, while minimal lowering is experienced at the location of the sand wave troughs. The most significant seabed lowering was found at IJWWFS Alpha (respectively -3.7 and -3.9 m as the 99.9% non-exceedance value), where sand waves are highest. Seabed lowering in IJWWFS Gamma (respectively -1.2 and -1.9 m as the 99.9% non-exceedance value) is predicted to be significantly lower compared to IJWWFS Alpha and IJWWFS Beta because of the absence of sand waves.

Comparison of the HSBL with the most recent measured bathymetry from 2020-2022 shows a bathymetric shape similar to the existing static part of the bathymetry, but typically several metres higher with +5.5 m as the 99%-non exceedance value. Opposite to seabed lowering, the largest potential rise seabed level is found at the current locations of the troughs just in front of the steep sand wave lee sides, with minimal rising at locations of the present sand wave crests.

The most significant seabed rise was found at IJWWFS Alpha (respectively 5.8 and 7.0 m as the 99.9% non-exceedance value), where sand waves are highest. Seabed rise in IJWWFS Gamma (respectively 1.2 and 2.3 m as the 99.9% non-exceedance value) is predicted to be significantly lower compared to IJWWFS Alpha and IJWWFS Beta because of the absence of sand waves.

Furthermore, a hindcast of seabed levels is made to assess the possible levels at which Unexploded Ordnances (UXOs) may be located. An important assumption in this method is that an UXO will never travel upwards and a typical UXO will self-bury to about half its height. To take into account the full range of possible object levels, the Lowest Object Level (LOL), the Highest Object Level (HOL) and the Best-Estimate Object Level (BEOL) over the period 1945-2022 were calculated.

The predicted seabed level changes presented in this study follow from the applied morphological analysis techniques, describing the physics and the natural variability of the analysed morphological system. No additional safety margins for design purposes have been applied. To support developers, this report discusses general considerations for cable routing in IJWWFZ. It is expected

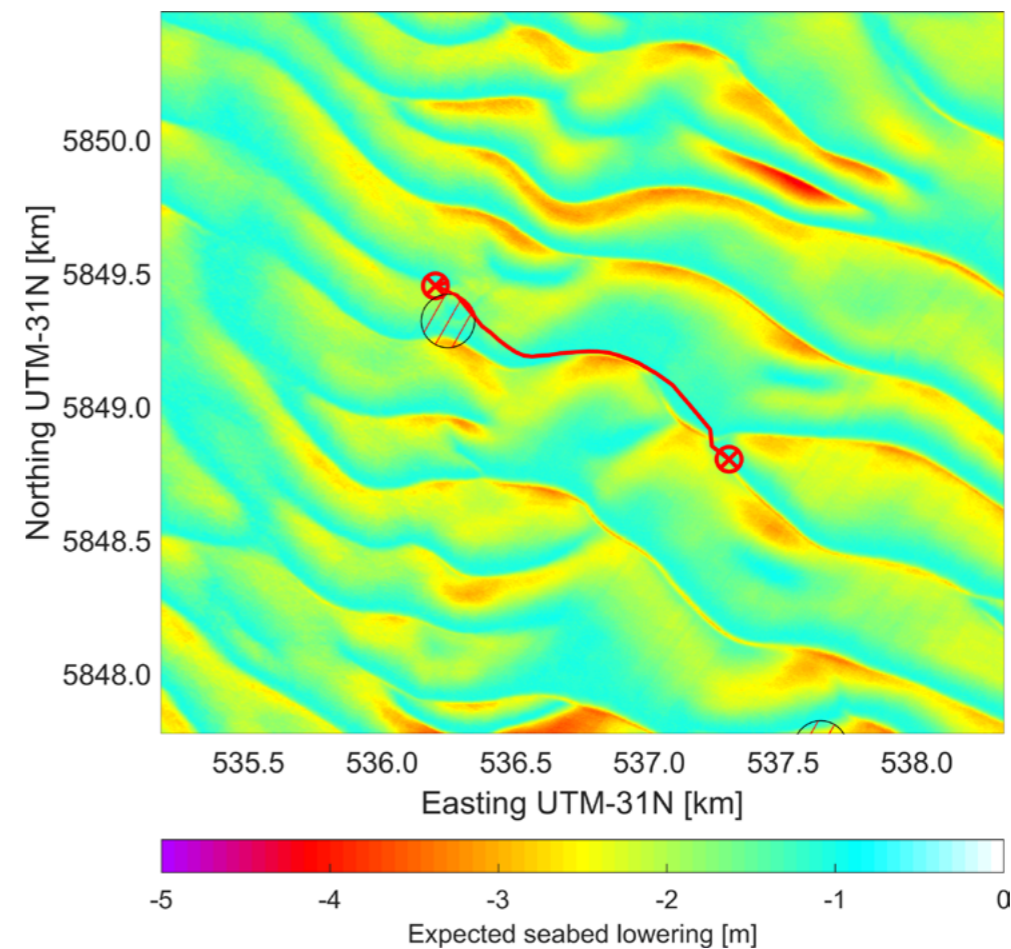


Figure 4.9.4 Example of cable route optimisation taking into account seabed dynamics

that cables can be buried sufficiently deep to avoid cable exposure (Figure 4.9.4), when smart cable routing techniques are adopted, which avoid the higher risk areas where the greatest variability in the seabed level is predicted.

4.9.4 Results for Scour mitigation assessment

In most situations, offshore structures can either be protected against scour or be designed such that scour development can be permitted. To decide which strategy is preferable for a certain foundation type and specific location, information was presented on how to predict the scour depth (when not protected) and how to protect against scour, both taking into account the morphodynamic scenarios of stable, lowering and rising seabeds.

It was concluded that for monopiles, an easily applicable, well-proven solution is to place the monopiles in either: 1) areas which display limited seabed dynamics; 2) to the north-east of the sand wave crests; or 3) on top of the sand wave crests and to apply a scour protection to maintain a more or

less fixed seabed level around the foundation. In the second case, a slightly longer pile is needed, while in the third case, a longer or thicker scour protection is recommended to cater for the lowering seabed. Other solutions are also possible, though, such as leaving out the scour protection completely at locations with a rising seabed, when scour protection costs outweigh the costs for additional steel consumption.

To illustrate the choice for a proper scour mitigation strategy, for monopiles, dynamic equilibrium scour depths (Figure 4.9.5), stable rock gradings (Figure 4.9.6) and required scour protection volumes were computed for the entire IJWFZ. Based on hydrodynamic timeseries scour calculations were made for the entire IJWFZ for three monopile diameters (10, 12 and 14 m). For the IJWFZ, scour depths between 9.3 and 12.3 m (95% non-exceedance values) were calculated for a monopile diameter of 12 m. This corresponds to 0.8 to 1.0 times the monopile diameter in which the relative scour depth decreases, and absolute scour depths increases with increasing diameters. Indicative calculations showed that, depending on the location

in IJWFZ a rock grading varying between 3-9" and 10-200 kg is sufficiently stable (during a design event with a return period of 50 years). In general, larger gradings are required in shallower waters. Smallest gradings are expected in the southwest of Site II and between the sand banks.

Gravity-Based-Structures (GBS) will typically need scour protection due to the severity of scour predicted to develop in the mobile seabeds in IJWFZ and the low tolerance of GBS to scour due to undermining risks. Locations where significant lowering of the seabed level was predicted are best avoided for GBS. Similarly, jacket structures are expected to experience significant scour development, but as long as they are not located in areas where the seabed is predicted to lower significantly and cable free spanning risks are mitigated by proper cable protection measures (such as application of cable stiffeners), the possibility exists for jacket structures to be designed for scour-free development. This does not hold for Suction Bucket Jackets where scour protection is, in most cases, recommended due to the limited penetration depth of

the suction cans and the large scour potential in IJWFZ. Other more cost-effective solutions (e.g. self-installable systems) look promising here and it is recommended they should be given due consideration by the developer.

With the provided maps for water depth, maximum seabed lowering, predicted scour depth, stable rock gradings and required scour protection volumes for each location, it can be computed which pile length is required, both for the situation that the pile will be protected and for the situation that the pile will be left unprotected. In case of protection, Figure 4.9.6 provides an indication of which scour protection is required. The provided information can assist the wind farm designer with optimising the locations for the wind turbine foundations and the selection of a cost-efficient and suitable scour mitigation strategy for each foundation.

The conclusions of this study can be used for a first estimate study only and more detailed studies would be required for the final designs. No additional safety margins for design purposes

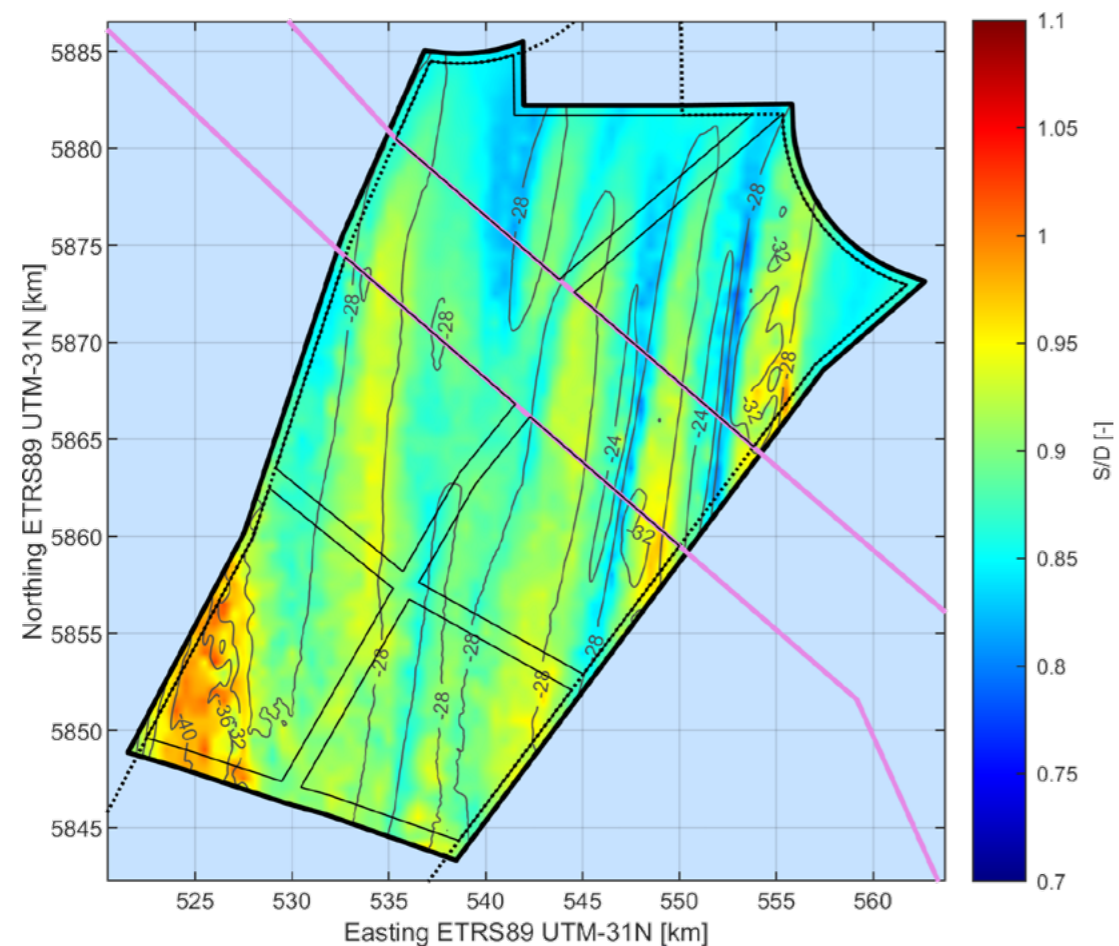


Figure 4.9.5 Estimated scour depth/monopile diameter of 10 m with a 95% non-exceedance probability

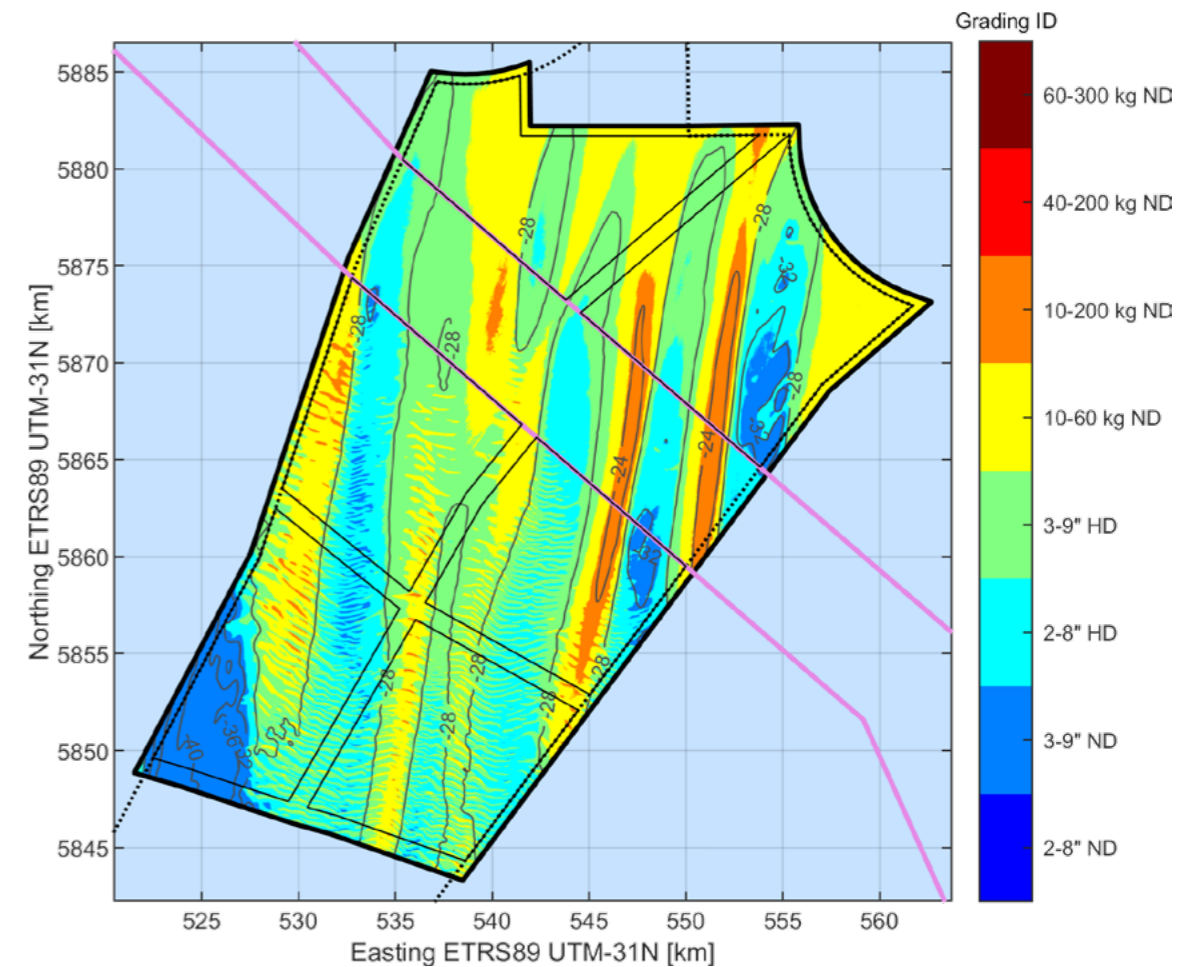


Figure 4.9.6 Indicative rock gradings in case of using scour protection consisting of rock for monopile foundations during a design storm with a return period of 50 years

have been applied. Further optimisation for scour predictions and/or scour protection designs can be achieved by means of physical model testing. In a morphodynamic area such as IJWWFZ, it is strongly recommended to account for predicted seabed changes from the beginning of the design process.

4.9.5 Deliverables

The results of the morphodynamics and scour mitigation study are summarised in a desk study report and associated data package (including a GIS archive and xyz data). The deliverables included:

- General background information regarding morpho-dynamic seabed features, of which sand waves are the most prominent in IJWWFZ;
- Geological and geophysical characterisation of the zone relevant to the dynamics of the seabed;
- Analysis regarding bed form migration speed and direction, including storm effects;
- Summary of performed numerical modelling for tides and sediment transport;
- Predicted future seabed levels (LSBL, HSBL, BEB);
- Predicted levels where UXOs can be expected (LOL, HOL, BEOL);
- Predicted maximum seabed slopes;
- Classification zones and considerations for cables and foundations;
- Description of how to deal with cable routing in dynamic seabed environments.
- Recommendations regarding possible scour mitigation strategies for IJWWFZ;
- Scour predictions for selected foundation types, e.g. monopiles, jacket structures and Gravity Based Structures;
- Map-based estimates for scour depths around monopiles, taking into account spatially varying hydrodynamics and water depth;
- Scour predictions for selected jack-up platforms (for installation purposes);
- Implications of edge scour around scour protections;
- Design requirements for scour protection;
- Description of currently available scour protection methods, e.g. rocks, mattresses, gabions, artificial vegetation, filter units;
- Map-based estimates for required rock gradings and rock volumes for scour protection, taking into account spatially varying hydrodynamic design conditions, water depth and seabed variations;
- Recommendations for eco-friendly scour protection designs.

4.9.6 Webinar

The study was discussed during a webinar on 1 June 2023. The webinar can be found on <https://offshorewind.rvo.nl>.

4.10 Offshore Wind and Water Site Assessment

Strategy

RVO has developed a strategy for offshore wind and water site assessments. This strategy includes the plan for the studies and investigations that will determine the site conditions for the wind farms planned in the Additional Offshore Wind Energy Roadmap 2030/31.

End users have access to:

1. The TNO Metmast IJmuiden data;
2. Monthly measurement campaign data and reports. The following datasets will be available: 1. Monthly reports (12) of metocean campaign data; 2. A Wind Resource Assessment incorporating 13 months of Metocean Campaign data will be published in November 2023;
2. A Metocean Assessment summary report incorporating 9 months of Metocean Campaign data will be published in December 2023. The MOODv2 database is continuously being populated with the Metocean Assessment dataset.



4.11 Metocean measurement campaign

4.11.1 Overview - Aims, Objectives, and Approach

The Metocean measurement campaign at IJVVWFZ aims to provide two sets of continuous meteorological and oceanographic (metocean) data that includes wind profiles with excellent quality and high availability. The campaign aims to enable stakeholders to carry out more accurate calculations of the annual energy yield and improve/validate metocean models that serve as input for the overall wind farm design. The data gathered during the campaign is also expected to lead to a lower uncertainty in wind and metocean data, resulting in a lower cost of capital in the business case for an offshore wind farm.

The campaign commenced in May 2022 and is expected to last for 24 months. RPS (a Tetra Tech Group Company) has been commissioned to measure, validate and provide these key meteorological and oceanographic (metocean) parameters in the North Sea, approximately 60 to 100 km west of Den Helder, the Netherlands. The data from the two buoys are validated against each other using correlation plots, demonstrating excellent agreement (Figure 4.10.1). The efficacy of the data is further confirmed by validation against independent data sources, thereby eliminating the possibility of measurement errors common to the two buoys.

During the planned 24-month programme, metocean data will be obtained from these fields using instruments fixed on floating systems. Measurement parameters include wind, wave, current, water-level, atmospheric pressure, and air temperature.

4.11.2 Supplier

RPS, a subsidiary of Tetra Tech, operates in six industries worldwide: real estate, energy, transportation, water, resources and defense and government services. Its services are divided into twelve clusters: project and programme management, design and development, water management, environment, management consultancy services, operation and development, planning and permits, health and safety, marine and coastal works, laboratories, training and communication and creative services. For this project, RPS Consultancy and Engineering BV in the Netherlands leads the project locally supported by global metocean expertise in the RPS Group.

4.11.3 Information about the buoys

RPS has been designing metocean buoys since 1990s. It delivers 10-minute averaged wind data which is transmitted near real time and daily transmission of raw data (figure 4.10.2). The buoy features a ZX 300M LiDAR sensor, with proven reliability. The company's buoys are:

- Highest **HSE** standards;
- 100% powered by renewable energy - **zero CO₂ emissions**;
- Certified to **Stage 2** by the Carbon Trust (2019);
- **Successful** deployments in Europe, United States, and APAC;
- **Onboard redundancy** for power, logging and data transmission;
- **Remote** monitoring and intervention capability;
- **Wave measurements**, currents, met, tides on same platform;
- **Mooring** designs expertise and measurement track record through recent typhoons.

4.11.4 Deliverables

The results of the metocean campaign are published on <https://offshorewind.rvo.nl>.

The data package includes data, a data report and pre-deployment validation and verification reports of the measurement systems, which can be found under "Validation Metocean Campaign." Monthly reports and datasets are disclosed under "Metocean Campaign Monthly Data & Reports." RPS provides an OceansMonitor Web that delivers real-time data for the buoys measuring at IJmuiden Ver and Nederwiek. The web-portal provides meteorological and oceanographic data measured in the past seven days for each buoy.

Separate data and reports are available for each month within the 24-month measurement period. For the first full year of the measurement campaign (May 2022 - May 2023), the data is summarised in a 12-month comprehensive dataset and published in October 2023. A final dataset and campaign report over all 24 months of data (May 2022 - May 2024) summarising all processed wind, wave and current data will be disclosed around August 2024. Both 12-month and 24-month data will be made available on <https://offshorewind.rvo.nl>.

4.11.5 Webinar

A webinar was held on 21st September 2023 where RVO, supported by RPS and DNV, presented the outcome of the first 12 months of Metocean measurements at the IJVVWFZ. The campaign achieved 95.5% average QC data return, underpinned by the excellent reliability of the RPS LiDAR buoy and after technical review of all reports and data by DNV. The webinar is available for viewing at [Wind en Water IJmuiden Ver - Offshorewind RVO](#).

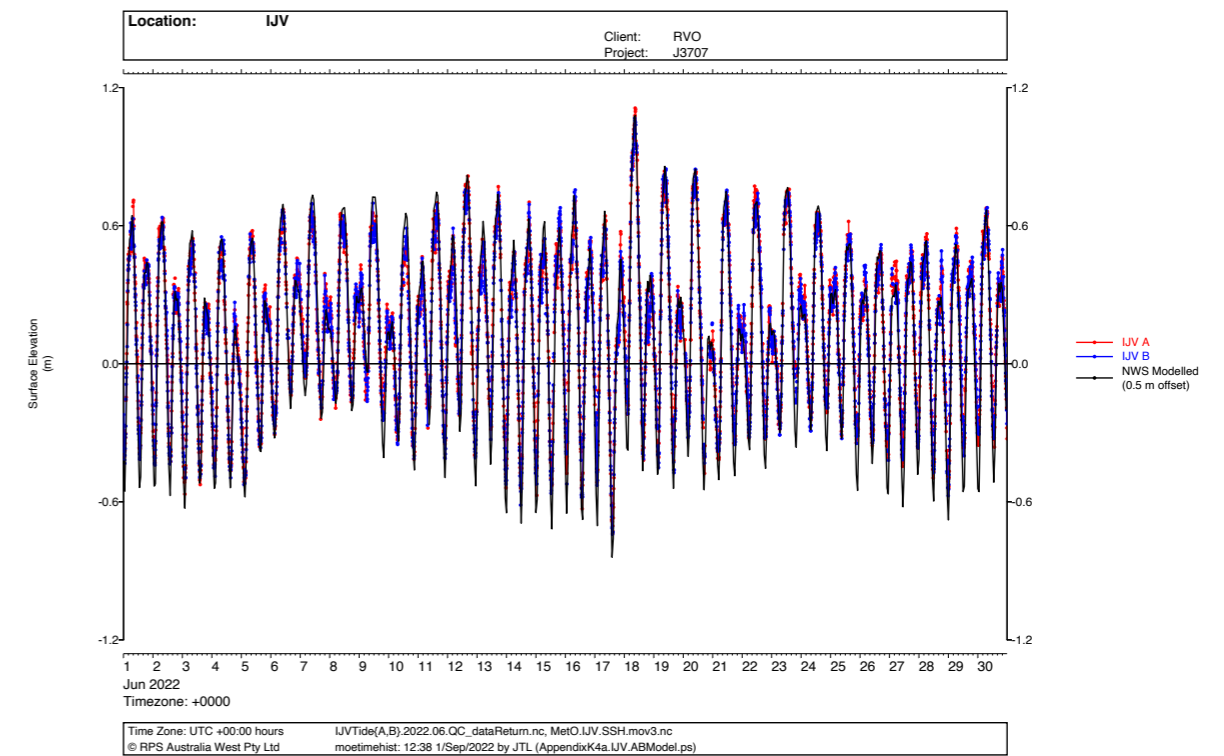


Figure 4.11.1 2 lidar buoys A and B vs NWS modelled tide

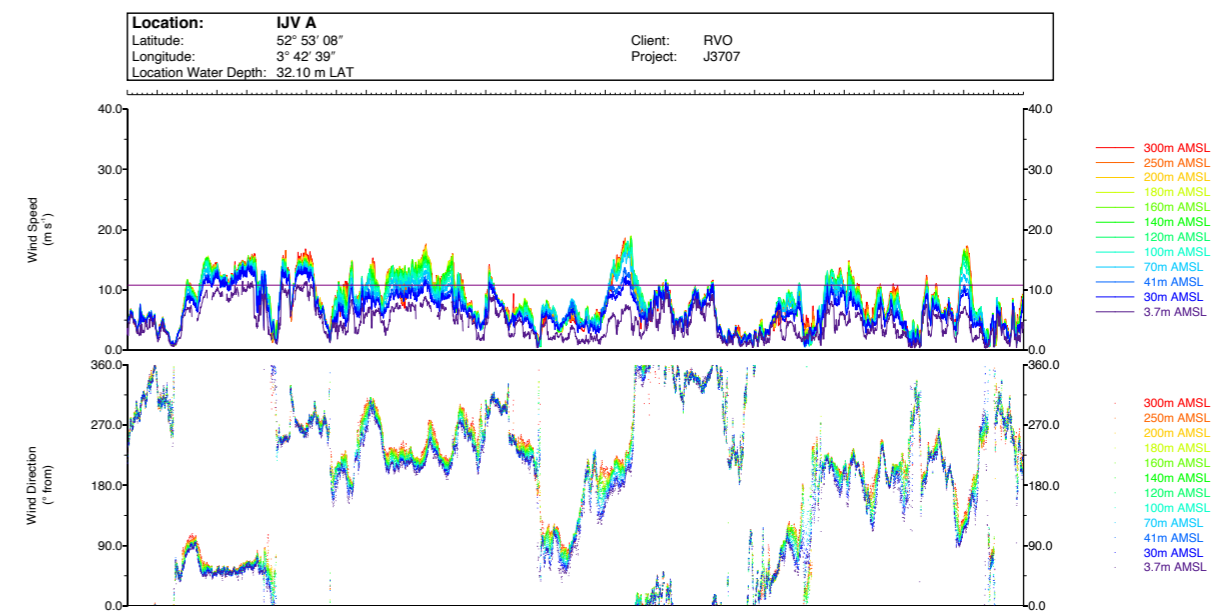


Figure 4.11.2 Example of wind profile data from RPS LiDAR Buoy in the IJVVWFZ

4.12 Metocean assessment

4.12.1 Overview - Aims, Objectives, and Approach

RVO requires the establishment of meteorological and oceanographic (metocean) conditions to serve as a crucial input for the safe and cost-efficient design, installation and maintenance of wind turbines and their related structures. The novelty of the study was to have a unified WRF model as input for both the wind resource assessment and the metocean assessment, thereby seeking alignment between the two assessments.

4.12.2 Supplier

The overall objective of the study undertaken by DHI is to provide accurate metocean conditions (wind, wave, water level and current) for IJmuiden Ver offshore wind farm. To establish the metocean conditions, DHI performed high-resolution numerical modelling for the period 1979-2022 covering not only the IJmuiden Ver wind farm zone but also all offshore wind farm search areas spanning across the Dutch Exclusive Economic Zone (EEZ). The numerical modelling was validated against the 8 months of measurement data at the IJmuiden Ver, covering the period from May until December 2023. Performance of the model has been very good as can be seen in Figure 4.12.1.

Normal and extreme conditions are established for winds, water levels, currents, and waves. The extreme conditions are established using the most advanced Joint Extreme Value Analysis (J-EVA) method. The analyses of normal and extreme metocean conditions are based on the same period of model data, 1979-15-01 to 2022-12-31 (44 years). Marginal and joint extreme values are established for return periods up to 10,000 years.

4.12.3 Results

The results of the meteorological and oceanographic (metocean) conditions in IJmuiden Ver will serve as input for the design, installation, and maintenance of wind turbines, inter array cables, substations and their support structures for companies submitting bids to develop the wind farm.

A comprehensive web-based MOOD database is provided to RVO, which enables users to access the modelling data and the analysis results through a user-friendly interface as shown in Figure 4.12.2.

4.12.4 Webinar

The study was presented and discussed in a webinar on 28 September 2023. The webinar is available on: <https://offshorewind.rvo.nl>.

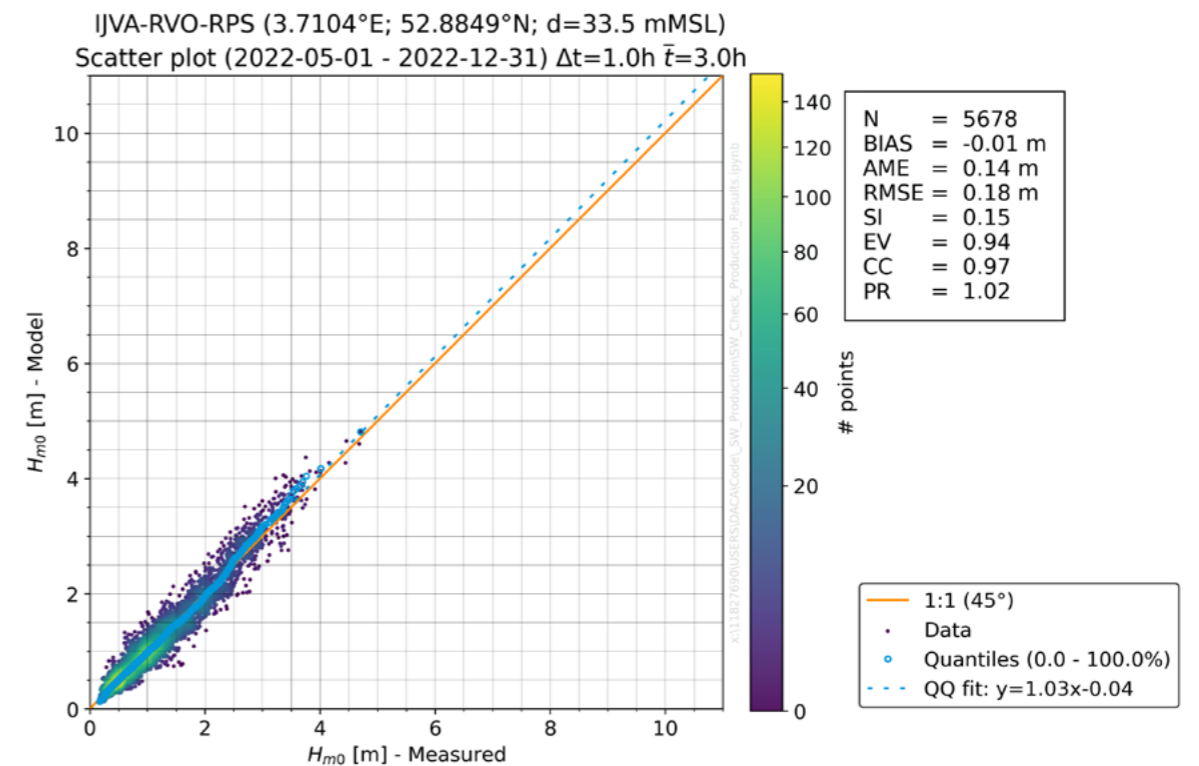
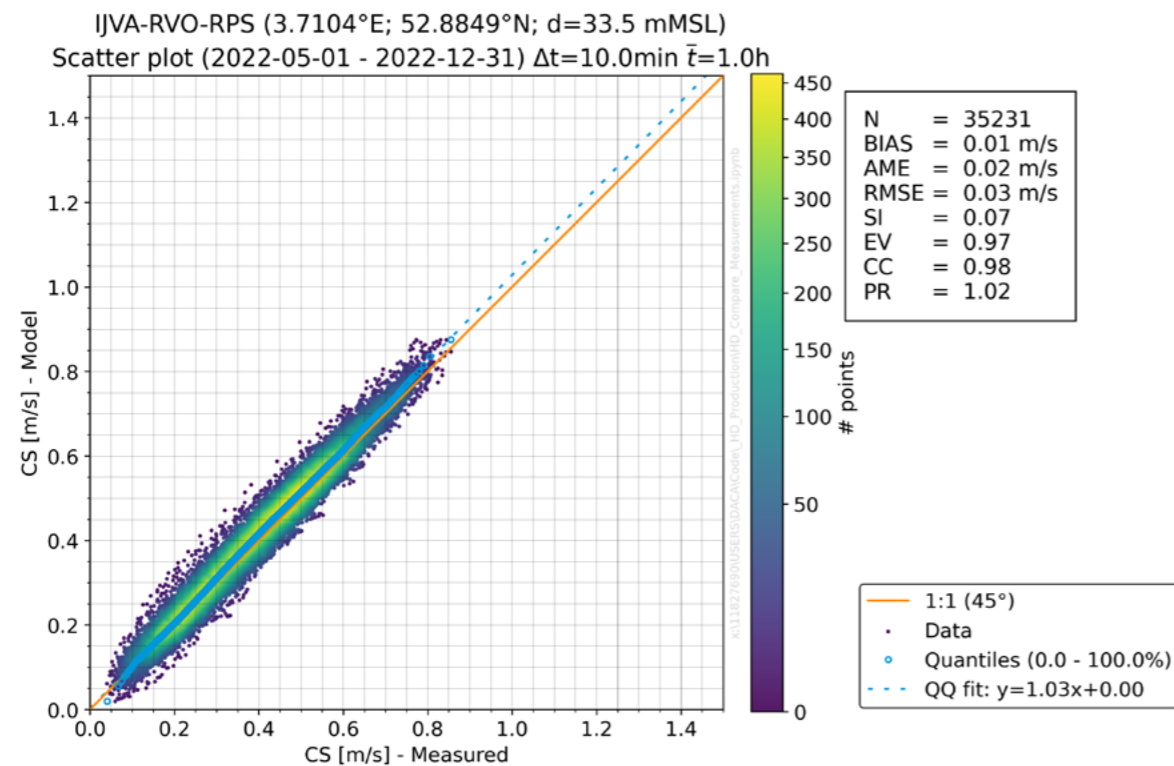
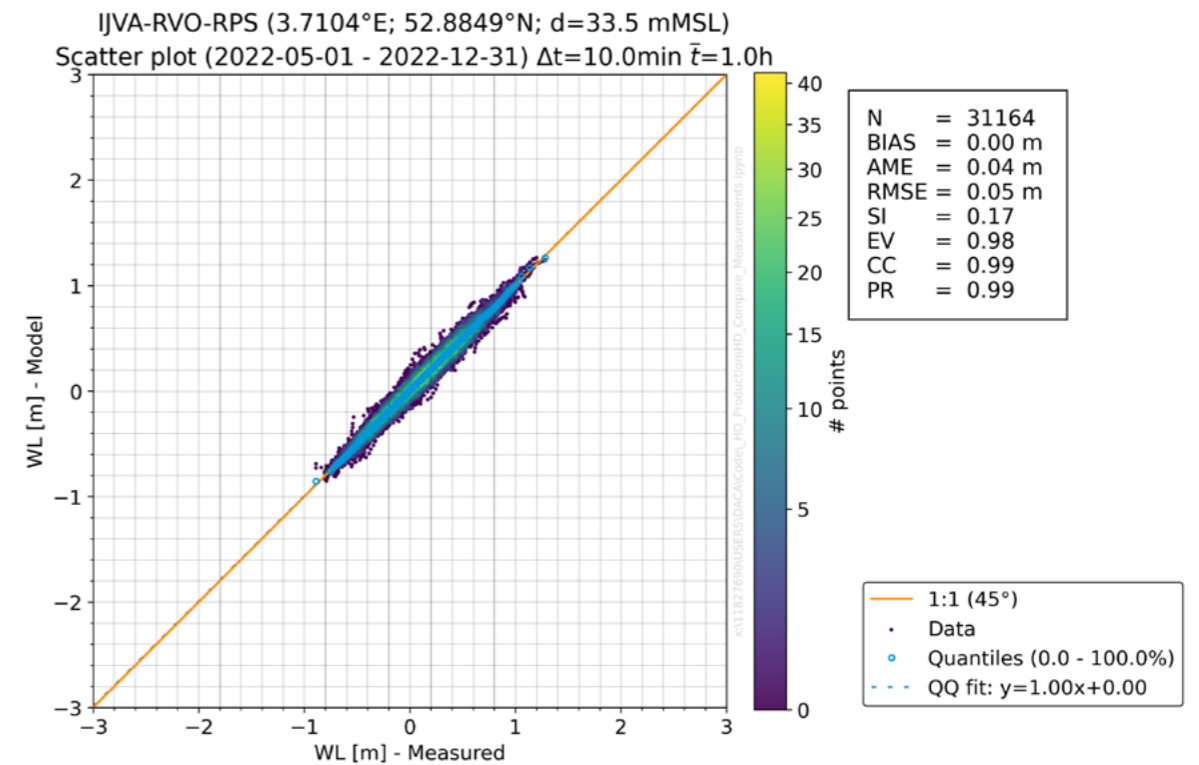


Figure 4.12.1 Validation plots indicating performance of the models

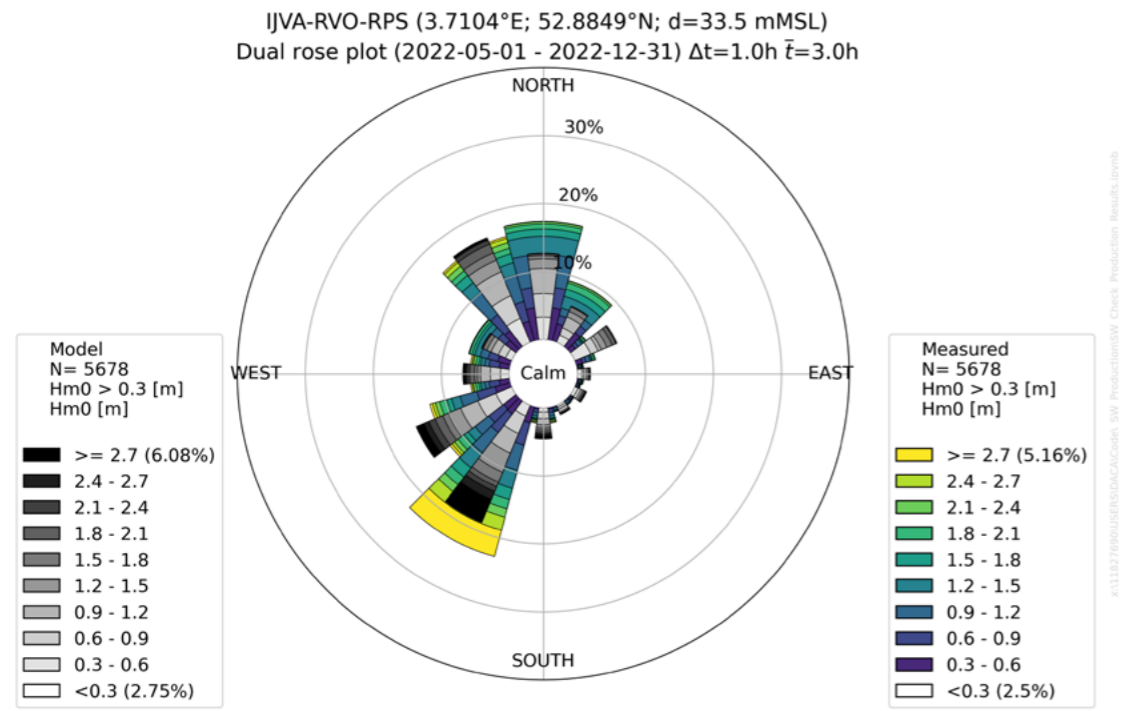


Figure 4.12.1 Validation plots indicating performance of the models

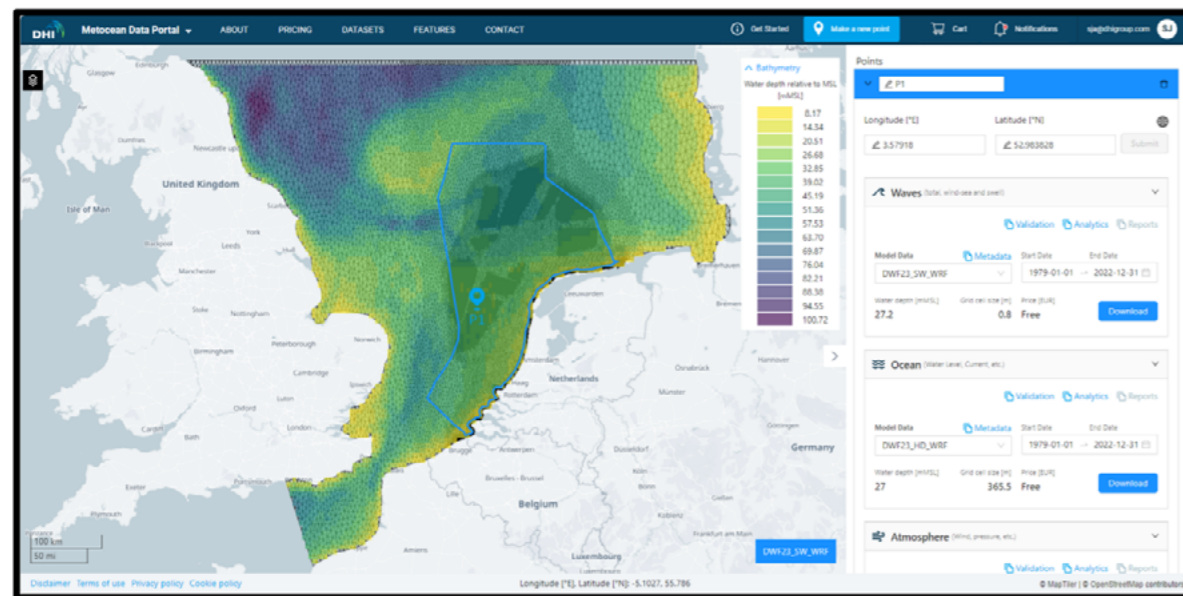


Figure 4.12.2 Snapshot of the MOOD database showing the feasibility area



4.13 Wind Resource Assessment

4.13.1 Overview - Aims, Objectives, and Approach

The DHI-led project consortium and the Wind Resource Assessment (WRA) package, directed by OWC and including collaboration with ProPlanEn, ArcVera, Innosea and C2Wind, has meticulously conducted a WRA for the IJWVZ, located approximately 62 km west of the Netherlands in the Dutch EEZ of the North Sea. The study aimed to evaluate the wind resource potential and develop a mesoscale model, Unified-WRF, to inform future offshore wind energy development within the three designated sites: IJWVFS Alpha, IJWVFS Beta and IJWVFS Gamma.

A comprehensive review of 14 offshore datasets from the Dutch and German North Sea was undertaken, classifying them into primary and secondary categories based on proximity, measurement integrity and duration. Four primary datasets, including on-site floating lidar systems (FLS IJV and FLS HKW), offshore met masts (MM IJmuiden) and vertical profiling lidars (Lidar K13-A), were deemed highly representative of the project area and were subjected to thorough analysis and quality checks by OWC.

The project involved a novel approach to obtaining long-term wind climate information, by creating a unified, gridded wind

dataset (Unified-WRF) capable of satisfying the requirements of both WRA and Metocean Assessment. The Unified-WRF model aimed to integrate and streamline wind resource and metocean analysis processes, enhancing the project's analytical accuracy.

The model was rigorously validated against short-term measurement datasets and other mesoscale models, exhibiting superior performance and alignment with long-term climate patterns.

The study incorporated a forward-looking climate change assessment using CORDEX projections under Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 scenarios, providing insights into future wind speed predictions and energy yield implications. A comprehensive uncertainty assessment was also conducted, addressing uncertainties in measurement, extrapolation, historical wind resource, spatial variation and climate change implications. The combined uncertainties were meticulously evaluated, ensuring a robust understanding of the project's potential and limitations.

The WRA delivers a thorough and nuanced analysis of IJWVZ's potential for offshore wind energy development. The integration of primary datasets, development of the Unified-WRF model, climate change projections and a detailed uncertainty assessment collectively provide a reliable and comprehensive resource for informing future developments in the region.

Table 4.13.1 IJWVZ nodal location mean wind speeds

Height [m]	Mean wind speed [m/s]					
	N1_ Alpha1	N2_ Alpha2	N3_ Beta1	N4_ Beta2	N5_ Gamma1	N6_ Gamma2
300	10.50	10.54	10.51	10.54	10.51	10.54
250	10.42	10.47	10.43	10.47	10.43	10.46
200	10.29	10.34	10.30	10.35	10.30	10.34
160	10.14	10.19	10.14	10.19	10.14	10.18
140	10.04	10.10	10.05	10.10	10.05	10.09
120	9.92	9.97	9.93	9.98	9.93	9.97
100	9.75	9.80	9.76	9.80	9.76	9.80
60	9.31	9.34	9.31	9.34	9.32	9.33
30	8.75	8.78	8.76	8.78	8.77	8.78
10	7.97	7.99	7.98	8.00	7.99	8.00

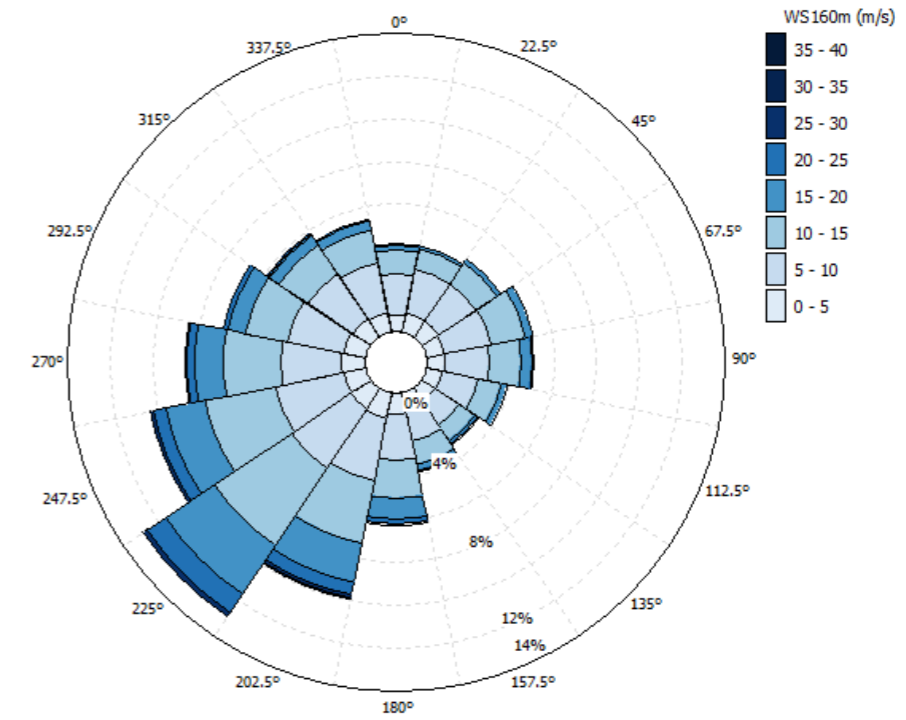


Figure 4.13.1 N2_Alpha2 160 m frequency wind rose

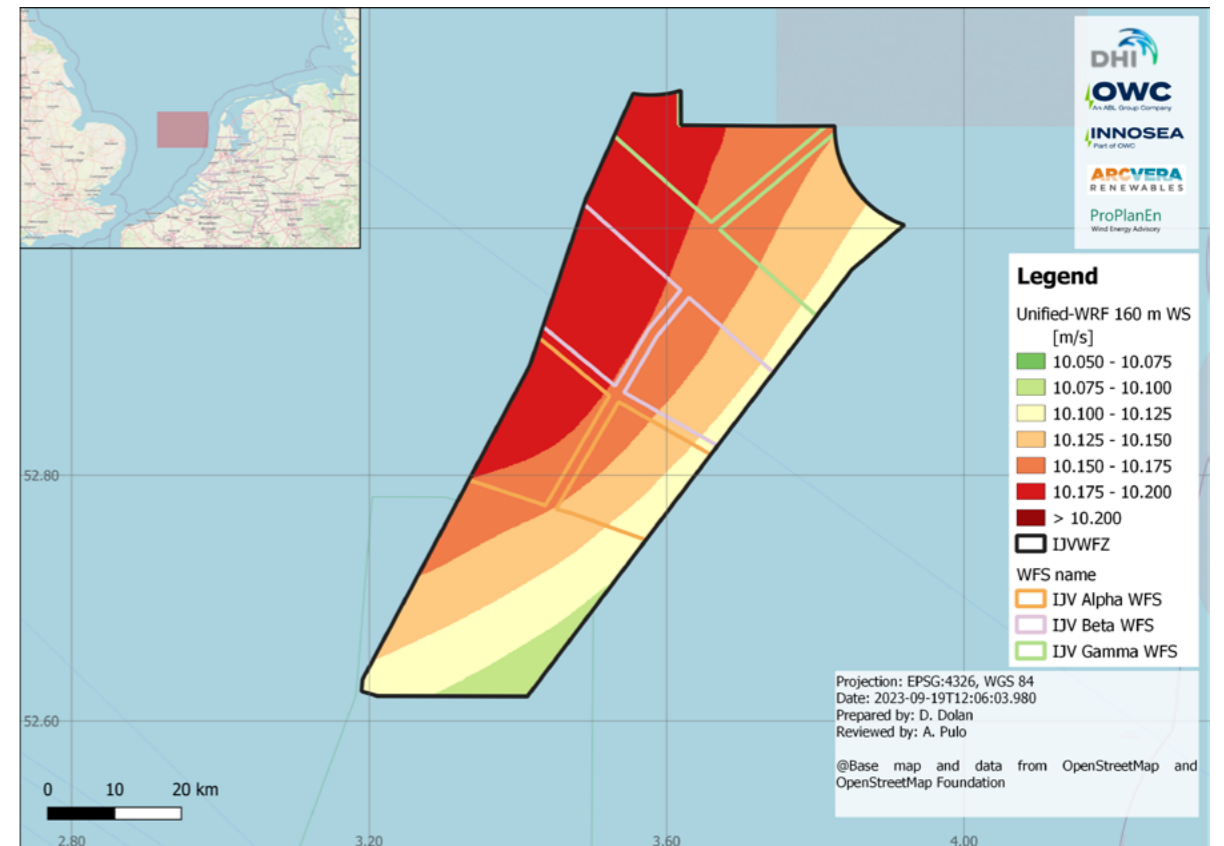


Figure 4.13.2 IJWVZ wind speed gradient map at 160 m

4.13.2 Results

The long-term wind speed at N3_Beta1 (FLS IJV location) at the height of 160 m was found to be 10.14 m/s, with a total associated combined uncertainty of 2.1% for the historical period. The uncertainty in the wind speed for the near-future scenario was found to be 0.2%. For future projections, the combined total uncertainty in long-term wind speed for the 10-year period was identified to be 2.7%.

Based on the Unified-WRF, a detailed output at 10-minute intervals was generated for the long-term climate of 13 years, including variables vital to wind energy analysis; wind speed, direction, air temperature and humidity, represented across ten different heights within the rotor layer. The long-term wind speed at the N2_Alpha2 node (MM Ijmuiden location) was found to be 10.19 m/s at the height of 160 m, with the prevailing west-southwest (225°) direction. The vertical and horizontal variation in long-term wind speed in the IJWWFZ is shown in Table 1 and the wind frequency rose is shown in Figure 4.13.1.

The Unified-WRF model can represent the mean wind speed and wind speed distribution at the primary measurement locations across the observed short-term period very well. Its performance is also very similar to KNW and DOWA, which are trusted mesoscale modelled datasets available across the Netherlands and the Dutch North Sea. The spatial variation of wind speed across IJWWFZ is around 0.05 m/s, as shown in Figure 4.13.2 and presented above Table 4.13.1.

4.13.3 Deliverables

The results of the WRA are summarised in a desk study report, published in November 2023. The report presents results for the following, at six specified output locations within the IJWWFZ, for the 13-year period spanning from 01 January 2010 to 31 December 2022:

- Long-term mean wind speeds at heights from 10 m to 300 m
- Long-term mean wind speeds at the height of 160 m at various probability levels (P10 – P90)
- Long-term direction frequency wind rose and long-term wind shear
- Omni and directional mean wind speed distributions, including Weibull parameters
- Long-term diurnal, monthly and year-to-year variations of mean wind speed
- Comprehensive uncertainty assessment

In addition, the complied Unified-WRF dataset is available on MetOcean On Demand (MOOD) with a granularity of 1.67 km, capturing 44 years of information with a 10-minute output cadence.

4.13.4 Webinar

The study was presented and discussed at two webinars on 28 September 2023. The webinars are available at:

- Unified-WRF: <https://offshorewind.rvo.nl>.
- WRA: <https://offshorewind.rvo.nl>.



5. Resources for further information

Several websites provide the most up-to-date information and status of all relevant studies, legal framework, and the application process for a permit. The most important of these are listed below.

- The most up-to-date information on site data, including the results of the IJWVWZ metocean campaign, can be found at offshorewind.rvo.nl. The site also contains maps, recordings of webinars and workshops, news, a Q&A, and revision log.
- More information on the permit, the Wind Farm Site Decisions and the FAQ can be found at <https://english.rvo.nl/information/offshore-wind-energy> and in Dutch at rvo.nl/windenergie-op-zee.
- Noordzeeloket provides information on several spatial topics concerning the North Sea, including offshore wind. Please visit noordzeeloket.nl/en/functions-and-use/.
- Windopzee.nl provides information in Dutch for the general public. Read more on windopzee.nl (Dutch only)
- Information by TSO TenneT, regarding the offshore grid connection, can serve as background information for offshore wind farm developers. Offshore grid documents (English) can be found at <https://www.tennet.eu/information-wind-farm-developers>.
- Interested in connecting with specific businesses or knowledge institutions within our supply chain? Do you have questions for trade organisations or governmental agencies? Please visit wind & water works (windandwater-works.nl)



Appendices

The appendices related to this PSD (Applicable Law, Environmental Impact Assessment and Memo Boundaries and Coordinates) will be made available when completed. These documents can be found at offshorewind.rvo.nl.



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