The impact of geophysical and geotechnical surveys on anchor selection and design – WFA a Case Study

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  - *Ocean Winds*

OCEAN WINDS

Organização

CPGT
Comissão Portuguesa de Geotecnia nos Transportes

CPMT
COMISSÃO PORTUGUESA de MELHORAMENTO de TERRENOS

Sociedade Portuguesa de Geotecnia

APDL
ADMINISTRAÇÃO DOS PORTOS DOURO • LEIXÕES • VIANA

AGENDA

- Introduction - Ocean Winds and Floating Technology
- Geophysical and Geotechnical surveys for anchor selection and design
    - The Ground Engineering Cycle
    - Desktop study
    - Year 1 campaigns
    - <u>Concept Engineering and anchor selection</u>
    - Subsequent stages
- The Wind Float Atlantic (WFA) Project
    - Project overview
    - Geophysical and Geotechnical surveys
    - Anchor selection
    - Anchor installation

OW OCEAN WINDS

- Ocean Winds and Floating Technology

WHO WE ARE?

Ocean Winds (OW) is an international company dedicated to **offshore wind** energy and created as a 50-50 joint venture, owned by **EDP Renewables** and **ENGIE**. Based on our belief that offshore wind energy **is an essential part of the global energy transition**, we develop, finance, build and operate offshore wind farm project all around the world.

When EDPR and ENGIE combined their offshore wind assets and project pipeline to create OW in 2020, the company had a total of 1.5 GW under construction and 4.0 GW under development. OW has been adding rapidly to that portfolio and is now on a trajectory to reach the 2025 target of 5 to 7 GW of projects in operation, or construction, and 5 to 10 GW under advanced development. Currently, **OW's offshore wind gross capacity already operating, in construction or with advanced development rights granted has reached 18.5 GW.**

OW, headquartered in Madrid, **is currently present in eight countries**, and primarily targets markets in Europe, the United States, selected parts of Asia, Brazil and Australia.

More information: **www.oceanwinds.com**

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ENGIE edp Renewables

• Ocean Winds and Floating Technology

OUR GLOBAL FOOTPRINT

Consists of **+** 18 GW (gross) with 16 projects in 8 geographies.

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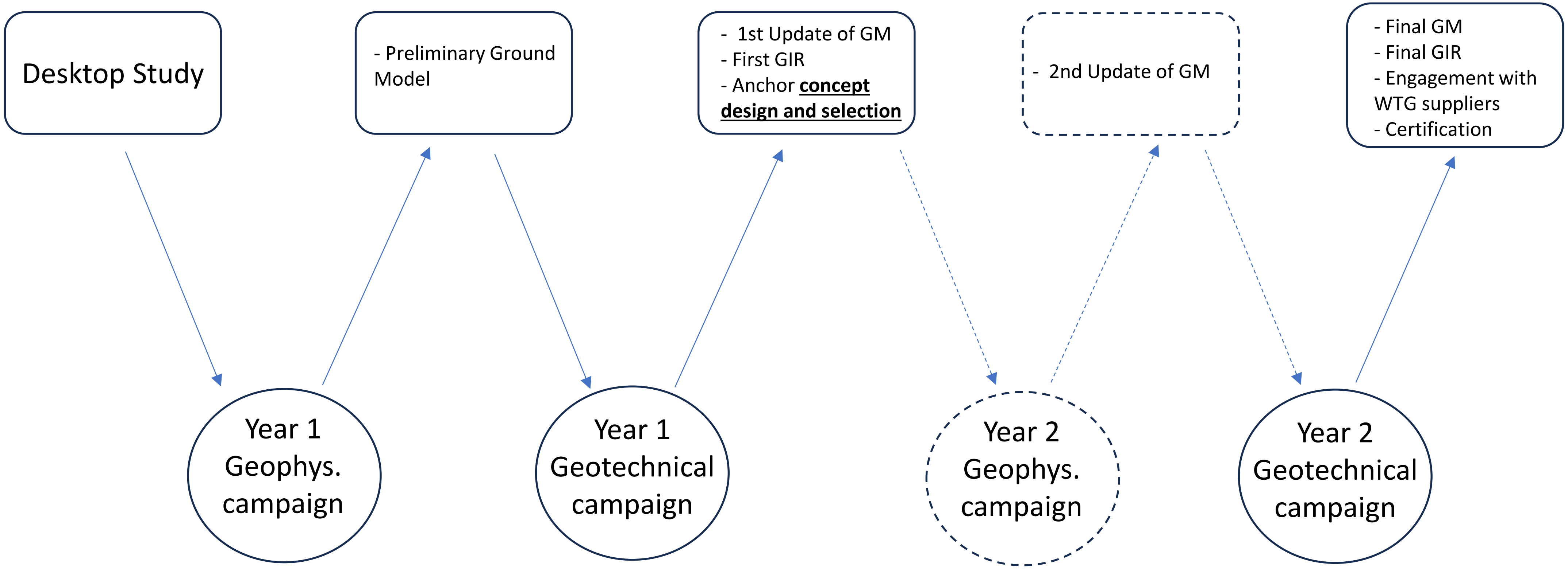
Bottom-fixed
Floating
OW Offices
OW HQ

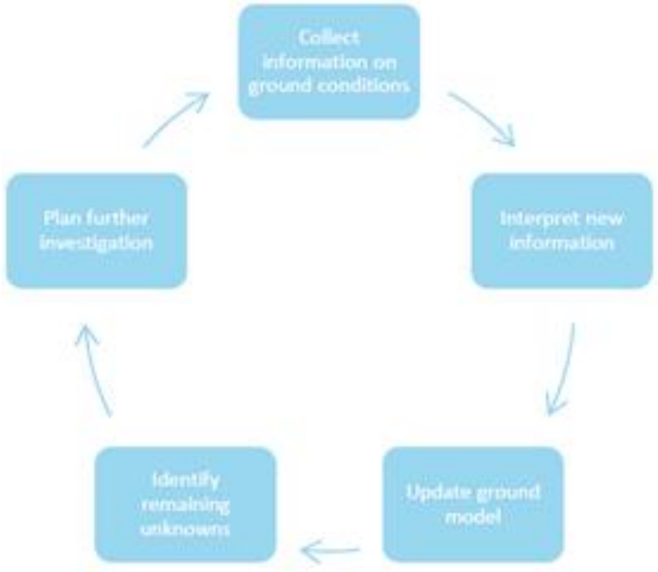
- Ocean Winds and Floating Technology
- Why Offshore Wind
  - Higher Wind resource and less turbulence
  - Large ocean areas available
  - Best spots in wind onshore are becoming scarce
  - Capacity for offshore wind is (in theory) unlimited

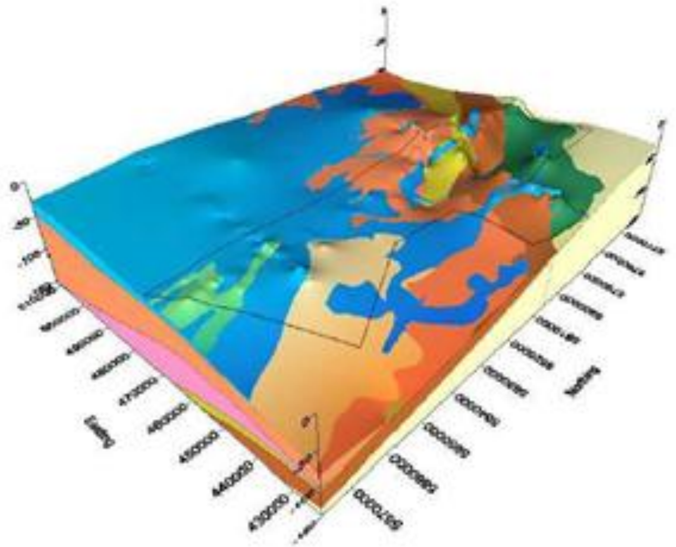
- Why Floating Offshore Wind
  - Limited spots in shallow waters
  - Larger ocean areas available
  - Less restrictions for offshore deployments and reduced visual impact
  - Huge potential around the world – USA, France, UK, Spain, Portugal

- Geophysical and Geotechnical surveys for anchor selection and design
- The Ground Engineering Cycle



- Geophysical and Geotechnical surveys for anchor selection and design
- The Desktop Study
  - Collection of historical data, publicly (or not) available
  - First regional geology interpretation
  - Expected geological units
  - Ground risk register (e.g. seismicity, mobility)
  - Physical constraints (cables, UXO potential, etc)
  - Development of conceptual GM
  - **Project feasibility** (from a developer perspective)
  - **Plan future surveys**





Process of ground model development (DNV-GL, 2018)

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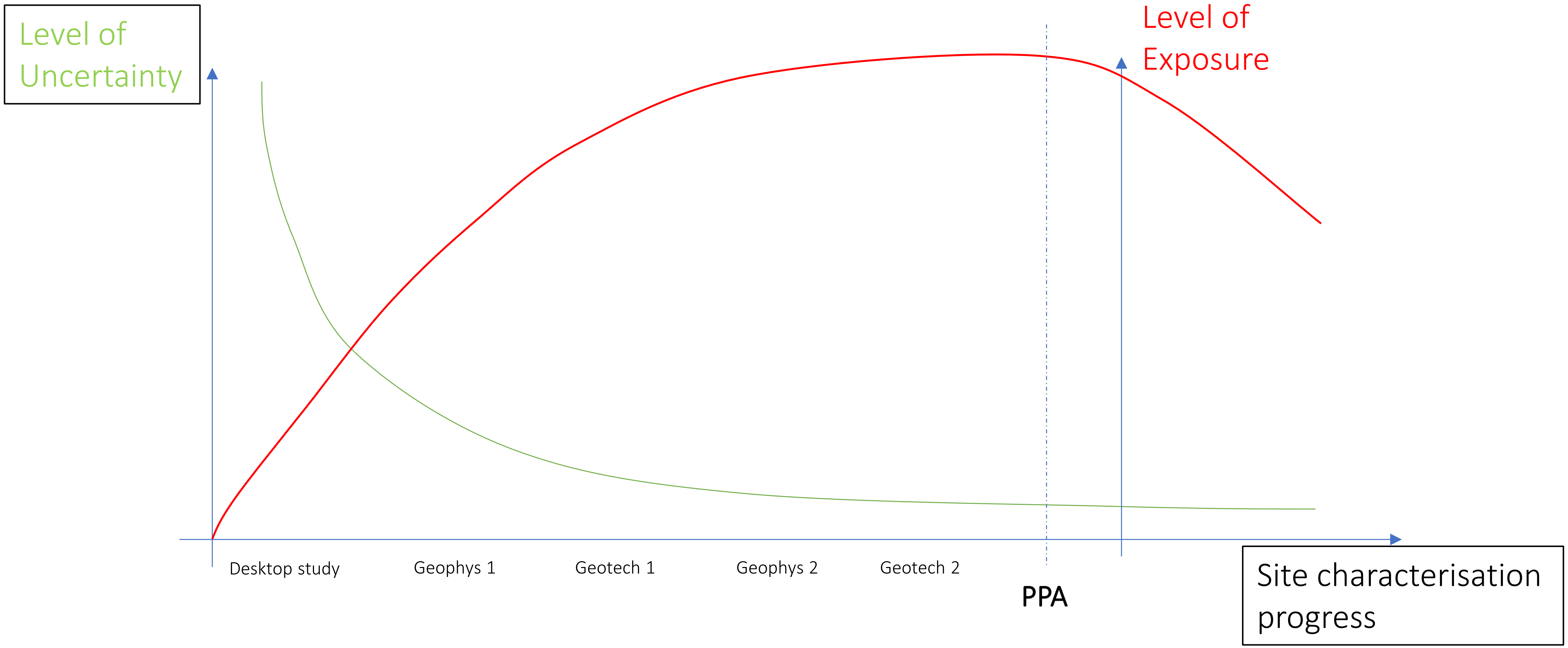
- Geophysical and Geotechnical surveys for anchor selection and design



- Geophysical and Geotechnical surveys for anchor selection and design
- Overview
  - Depending on geography requirements serves both permitting and engineering
  - Some countries provide this data during tender phase (with different degrees of quality)
  - From a permitting perspective: demonstrate developer knowledge and feasibility. Environmental reasons
  - From an engineering perspective: anchor concept design (pre-FEED)
  - Big DEVEX investment for developers
  - Current challenges: market contraints

- Geophysical and Geotechnical surveys for anchor selection and design
- Year 1 Geophysical Survey
  - Bathymetric survey. Seafloor morphology
  - Correlate geological units with seismic layers
  - Framework for a first Ground Model
  - Detect uncertainties and data gaps
  - Plan Year geotechnical campaign locations and depths
  - Typical means are
    - Multibeam Echosounder (MBES)
    - Side Scan Sonar (SSS) – special importance for DEA
    - Seismic Reflection: Sub-bottom profiler (SBP) and Ultra High Resolution (UHR) Seismic
    - Magnetometer

- Geophysical and Geotechnical surveys for anchor selection and design
- Year 1 Geophysical Survey
  - Scope is highly dependent on project and ground conditions
  - Both dense grids 2D UHR or 3D UHR are being considered by developers
  - Reason: cost, logistics, market constraints planning, lateral variability

Objective	Method	Grid	Penetration	Notes
Seafloor topography	Multibeam bathymetry (MBES)	Full field coverage with a 50% or 100% overlap (with a minimum overlap of 20%)	N/A	Processing of MBES data by backscanning is recommended Single-trace echo-sounder to calibrate the MBES
Sea floor morphology **Nature of surface sediments**	Side Scan Sonar (dual frequency)	Full field coverage with a 50% to 100% overlap (ideally same as MBES)	N/A	R: collect samples to calibrate sediments nature: grab sampler (or gravity corer)
Stratigraphy	Single- or multi-trace seismic reflection Source: boomer or sparker for significant penetrations; R: to be complemented with pinger/chirp for shallow penetrations	250m x 1000m (cross lines) grid	Typically 50m -100m depending on soil/rocks conditions Resolution: <1m in depth Pinger/chirp: Resolution: <0.3m	Full field coverage Surface seismic reflection required on all cables routes

Recommended program for a preliminary geophysical survey (CFMS, 2020)

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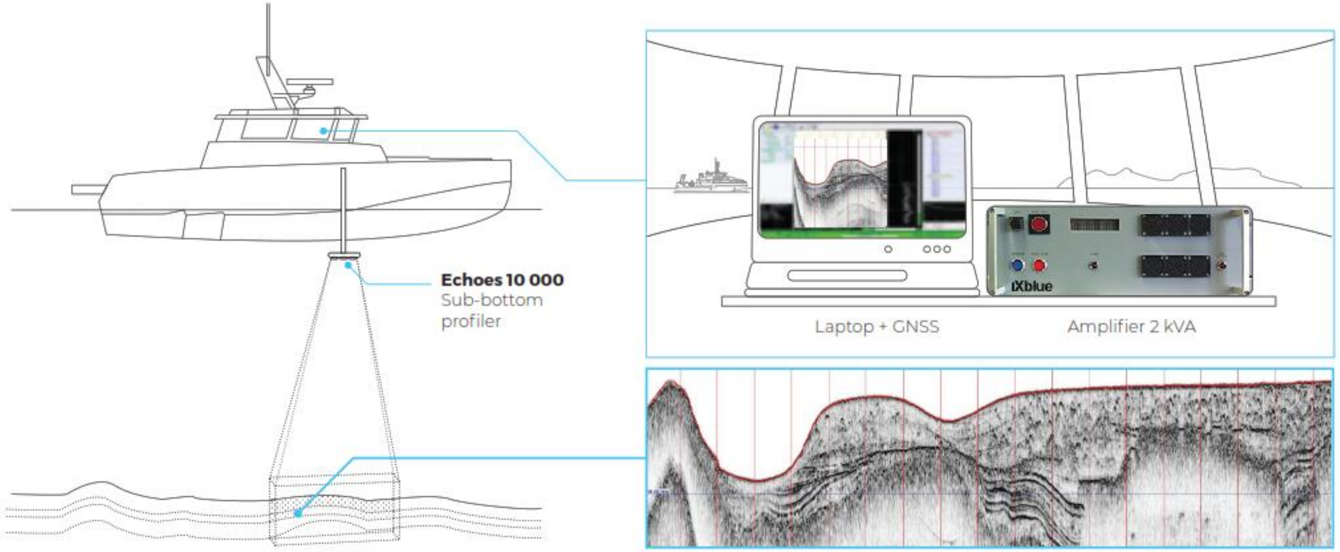
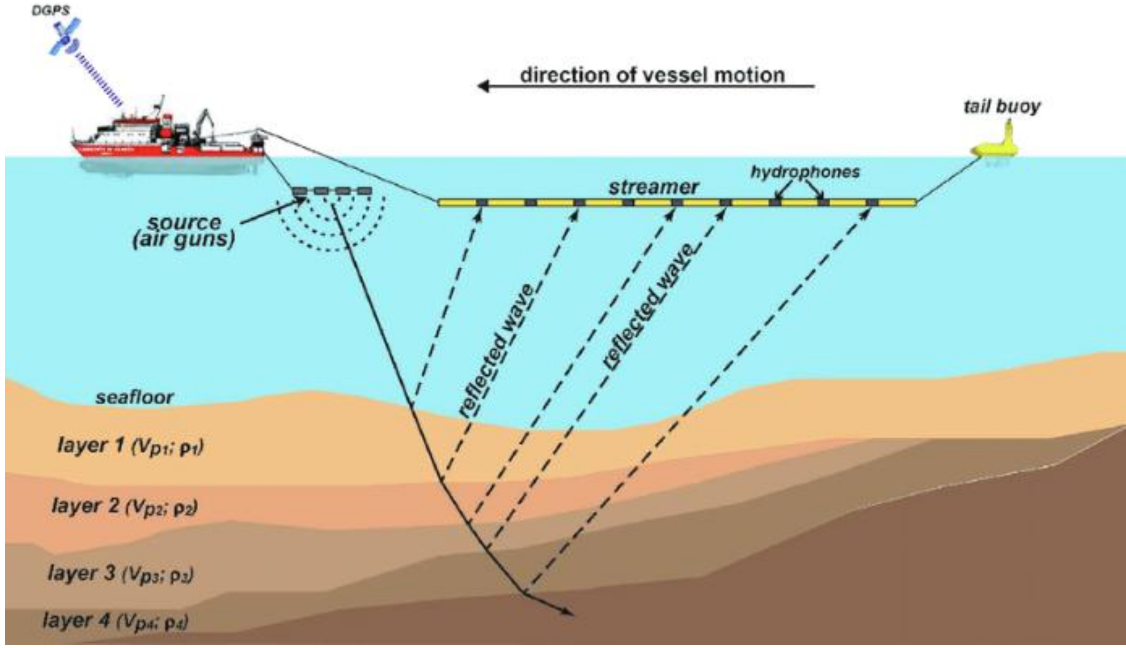
- Geophysical and Geotechnical surveys for anchor selection and design
- Year 1 Geophysical Survey
  - Equipment



Sub-bottom profiler (Water Solutions)



Multi-channel seismic system schematic (A.L. Cameselle)

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- Geophysical and Geotechnical surveys for anchor selection and design
- Year 1 Geotechnical Campaign
  - Locations (should be!) selected based on seismic layers
  - Correlation with geophysical data, refinement of GM and engineering properties
  - Realistic anchor dimensioning
  - Combination of CPTs and BH sampling
  - The scope will largely vary depending on soil variability
  - Typical means
    - Seabed CPTs
    - Down the Hole (DtH) CPTs
    - Sampling BHs
    - Vibrocores (VCs)

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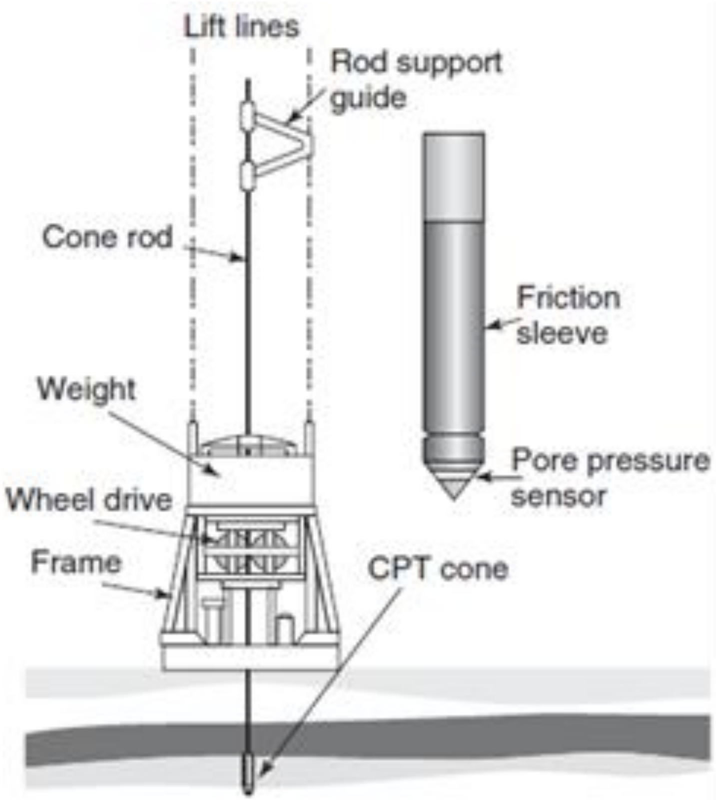
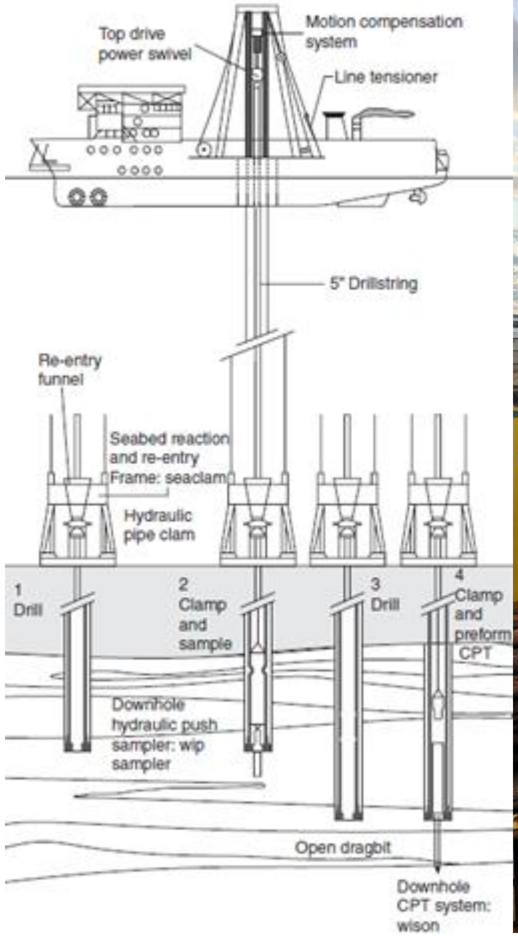
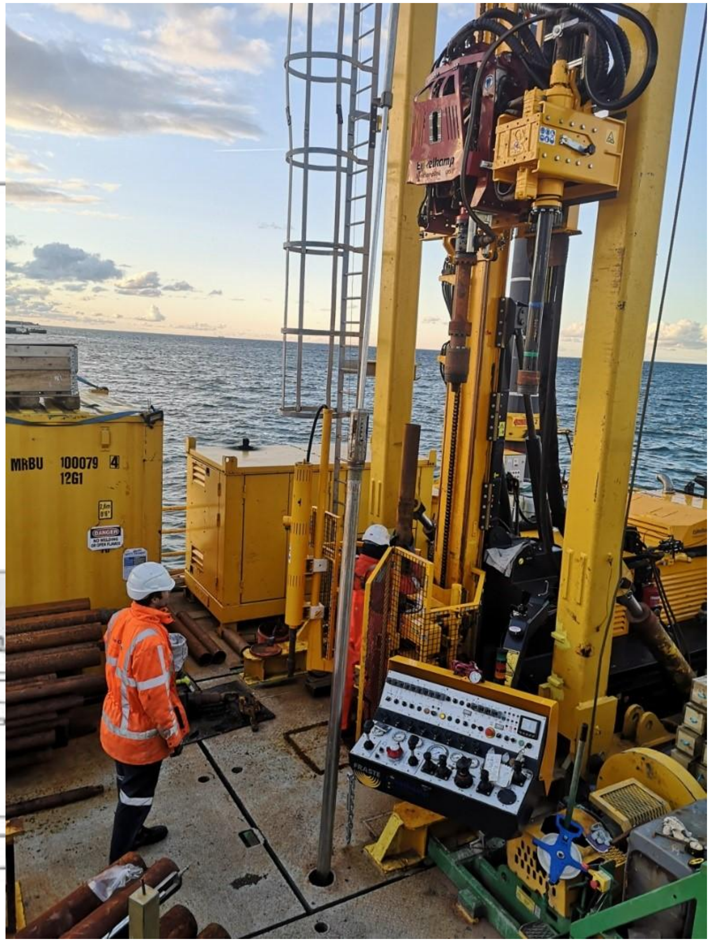
- Geophysical and Geotechnical surveys for anchor selection and design
- Year 1 Geotechnical Campaign
  - CPT



Seabed units to deploy the CPT offshore (J.L. Briaud, 2013; Robertson, 2015)

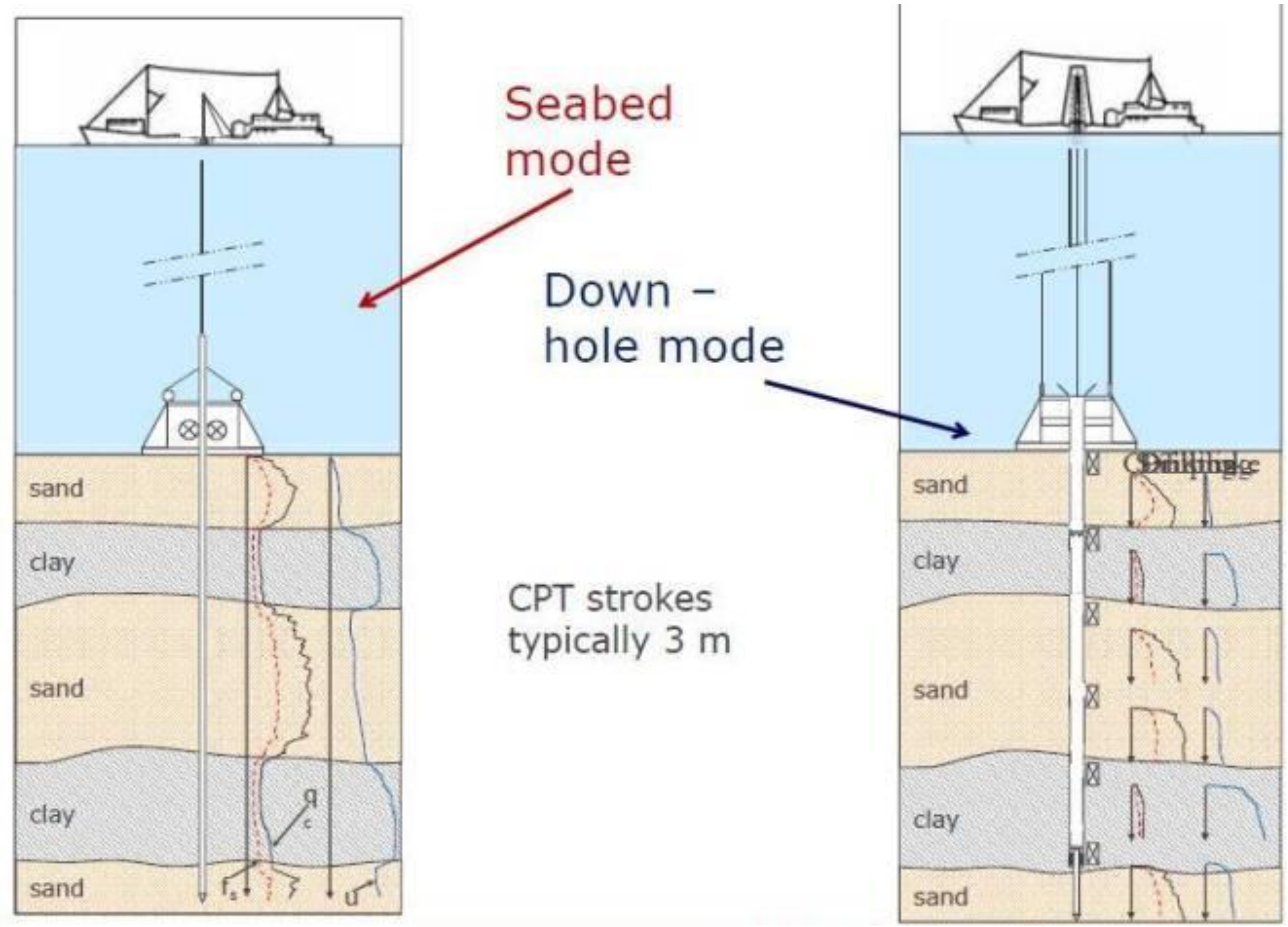
- Geophysical and Geotechnical surveys for anchor selection and design
- Year 1 Geotechnical Campaign
    - CPT





Drilling, sampling and in situ testing through the drill string. (ISSMGE, 2005; Lankelma)

- Geophysical and Geotechnical surveys for anchor selection and design
- Year 1 Geotechnical Campaign
  - CPT



- Geophysical and Geotechnical surveys for anchor selection and design
- Year 1 Geotechnical Campaign
    - Seafloor drill

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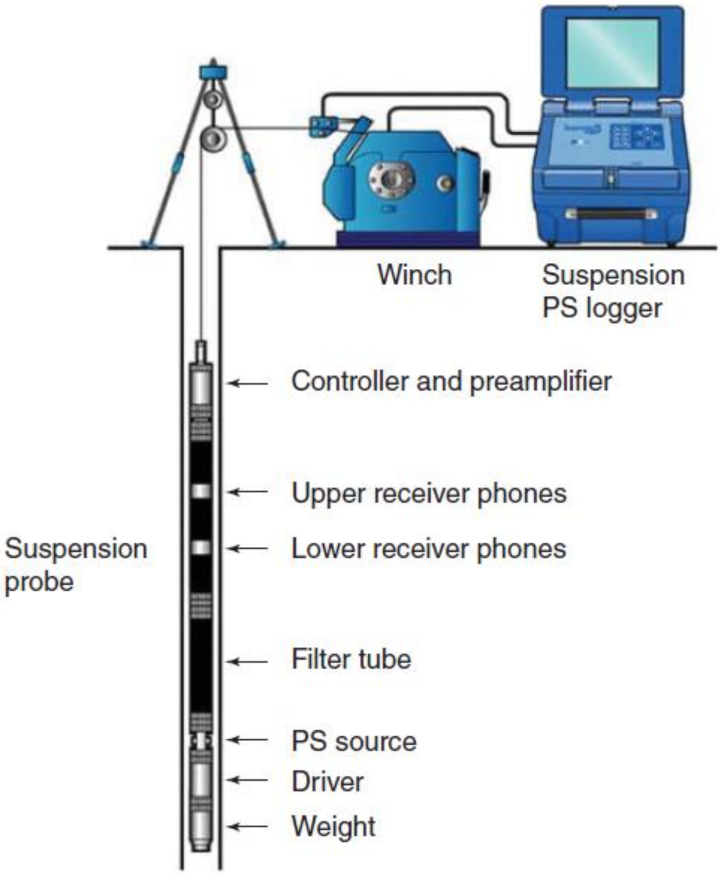
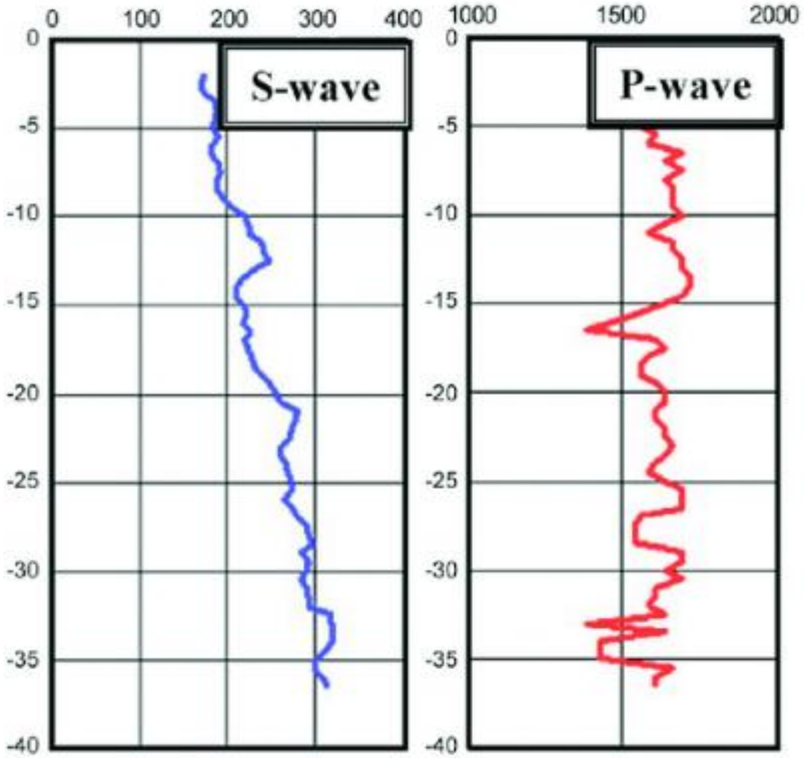
- Geophysical and Geotechnical surveys for anchor selection and design
- Year 1 Geotechnical Campaign
  - Geophysical techniques





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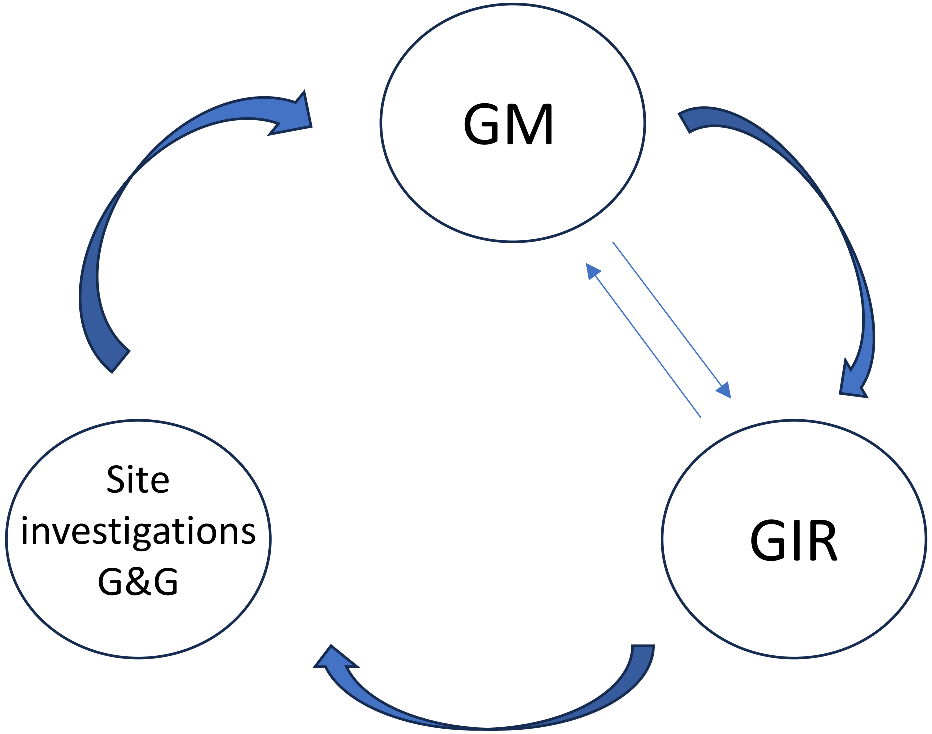
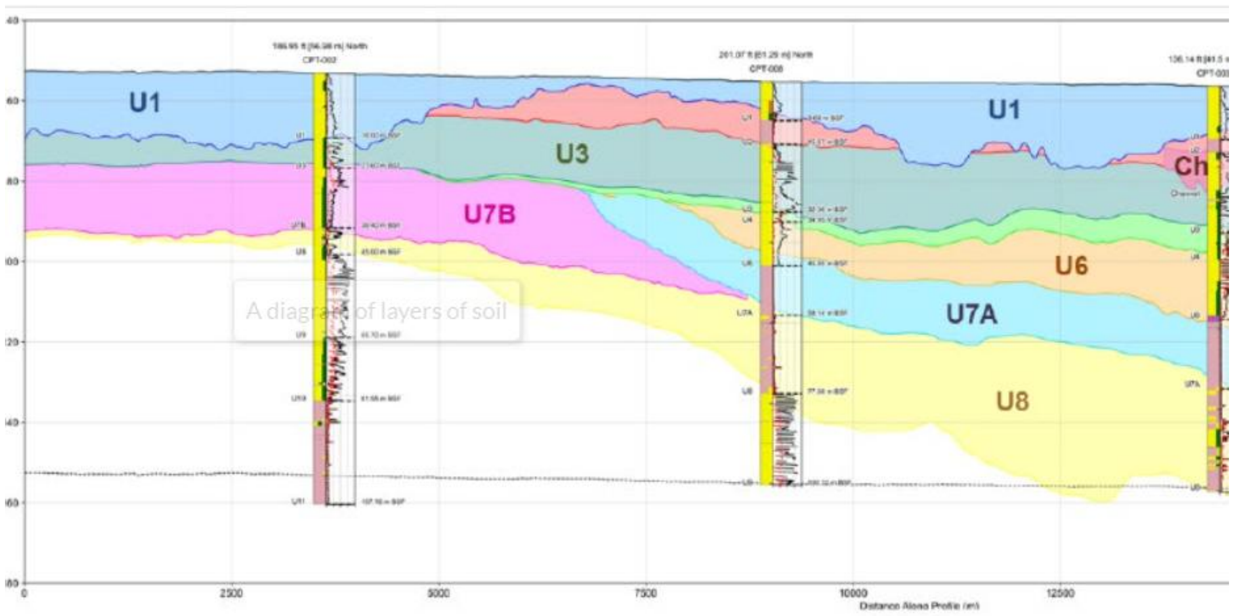
- Geophysical and Geotechnical surveys for anchor selection and design
- Year 1 Geotechnical Campaign
  - Laboratory testing
    - Highly dependent on anchor type
    - Year 1 campaign aims at covering most likely anchor types
    - Behaviour of DEA is completely different to pile anchors
    - Typically done in stages
    - Bottleneck risk

- Concept Engineering and anchor selection
- Two main components form the engineering cycle
  - The Ground Model (GM)
  - The Geotechnical Interpretative Report (GIR)
  - They feed the subsequent engineering stages, analyses, design and reporting



- Concept Engineering and anchor selection
  - The GM and GIR are live documents starting at desktop study and evolving towards Year 2 campaigns and certification
  - The GM is of special importance for anchor selection, especially in terms of installation and risks
  - The GIR focuses on anchor sizing



Ground model extract (Ocean Winds)

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- Concept Engineering and anchor selection
- Selection criteria
  - Water depth
  - Mooring system (loading direction)
  - Installation
  - Soil conditions
    - Presence of rock
    - Cemented layers or boulders
    - Very soft sediments
  - Anchor dimensions combined with costly installation can lead to unfeasible projects

- Concept Engineering and anchor selection
- Anchor types
  - Pile anchors
    - Flexible: wide range of soil conditions including rocks
    - Costly installation but flexible (impact or vibro driven)
    - Mitigation possible if early refusal
    - Can withstand lateral and vertical loading
    - Sizing: axial pile capacity and lateral resistance
    - Installation: driveability studies

- Concept Engineering and anchor selection
- Anchor types
  - Suction anchors
    - Can present a good alternative in terms of dimensions
    - Fast and noiseless installation
    - Installation is very sensitive to soil conditions
    - Micrositing not as easy as O&G industry
    - Good alternative in soft sediments and large water depths
    - Can withstand lateral and vertical loading
    - Risky installation in large scale commercial projects
    - Sizing: analytical axial and lateral capacity combined with FEM
    - Installation: static suction assisted installation

- Concept Engineering and anchor selection
- Anchor types
  - Drag embedded anchors
    - Not suitable for large water depths
    - Can’t withstand vertical loading
    - Easy and cost-effective installation
    - Optimal anchoring solution if soil conditions allow
    - Lack of precision during installation
    - Sizing: design charts and contractor experience
    - Installation: empirical (qualitative analysis of ground conditions)

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- Concept Engineering and anchor selection
- Anchor types
  - Dynamically or suction installed plate anchors
    - Improved installation
    - Increased uplift capacity
    - Easy and cost-effective installation
    - Restricted to certain penetration depth (DEPLA) or highly sensitive to soil conditions (SEPLA)
    - Emerging technology

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- Concept Engineering and anchor selection
- Anchor selection
  - Feasibility Matrix – selection of the anchor type(s) to progress concept design
  - Feasible area mapping vs project capacity – project still economically feasible?
  - Number of anchor types required in a single site?
  - Two typical approaches for sizing and installation assessments
    - Anchor sizing and installation based on geotechnical data
    - Anchor sizing and installation based on geotechnical data and ground model
  - Design based on GM generates extrapolated soil profiles at each anchor position and assigns geotechnical properties at each layer based on the GIR
  - Sizing and installation assessment is carried out at each profile
  - Typically done in sites where anchors represent a big impact in capex
  - Required good geophysical and geotechnical data and GM

- Subsequent stages
- Year 2 surveys
  - Year 2 geophysical
    - Important for bathymetry and seabed mobility
    - Data gap covering if Year 1 was a light campaign
    - Inter-array cable and micrositing
  - Year 2 geotechnical
    - Geotechnical soundings at each anchor location
    - Industry is evolving in that front due to new challenges and market constraints
- Start of Front End Engineering Design (FEED)
  - Engagement with turbine supplier
  - Start of Integrated Load Analysis (ILA) process – typically 2 or 3 iterations
  - Detailed design – Certification – Approved for Construction (AFC)
- Installation

- The WFA project
- Overview

**THE WORLD'S
1ST SEMI-SUBMERSIBLE
FLOATING OFFSHORE
WIND POWER PLANT**

3 UNITS
Total **25 MW**

European Investment Bank

LOCATION	• Atlantic Ocean: **18 km** of the coast of Viana do Castelo, Portugal • Water depths around **100 m**, in an area of sand and sediments
TECHNOLOGY	• 3 WindFloat® floating platforms, with 3 mooring lines each • 3 wind turbines Vestas V164 – **8.4 MW** each
CONNECTION	• Electrical collecting system with dynamic cables at **60 kV** • Dry-mate connection to REN's submarine cable (Portuguese TSO)
PARTNERS	• Asset owned by WindPlus: **Ocean Winds** is the main shareholder; **Tokyo Gas** and **Repsol** are the other two shareholders
FINANCING	• WindPlus shareholders' funds + **EIB** Project Finance + **EU** NER300 Funding + **PT** Environmental Fund (FA)
REMUNERATION	• Combined scheme: **PT** FiT + **FA** Supplement + **EU** NER300 Program

KEY DATES

- FID & Construction Start: 02/2018
- Installation Start: 07/2019
- Grid Connection: 12/2019
- Commercial Operation: 02/2020
- Operation Phase Start: 09/2020

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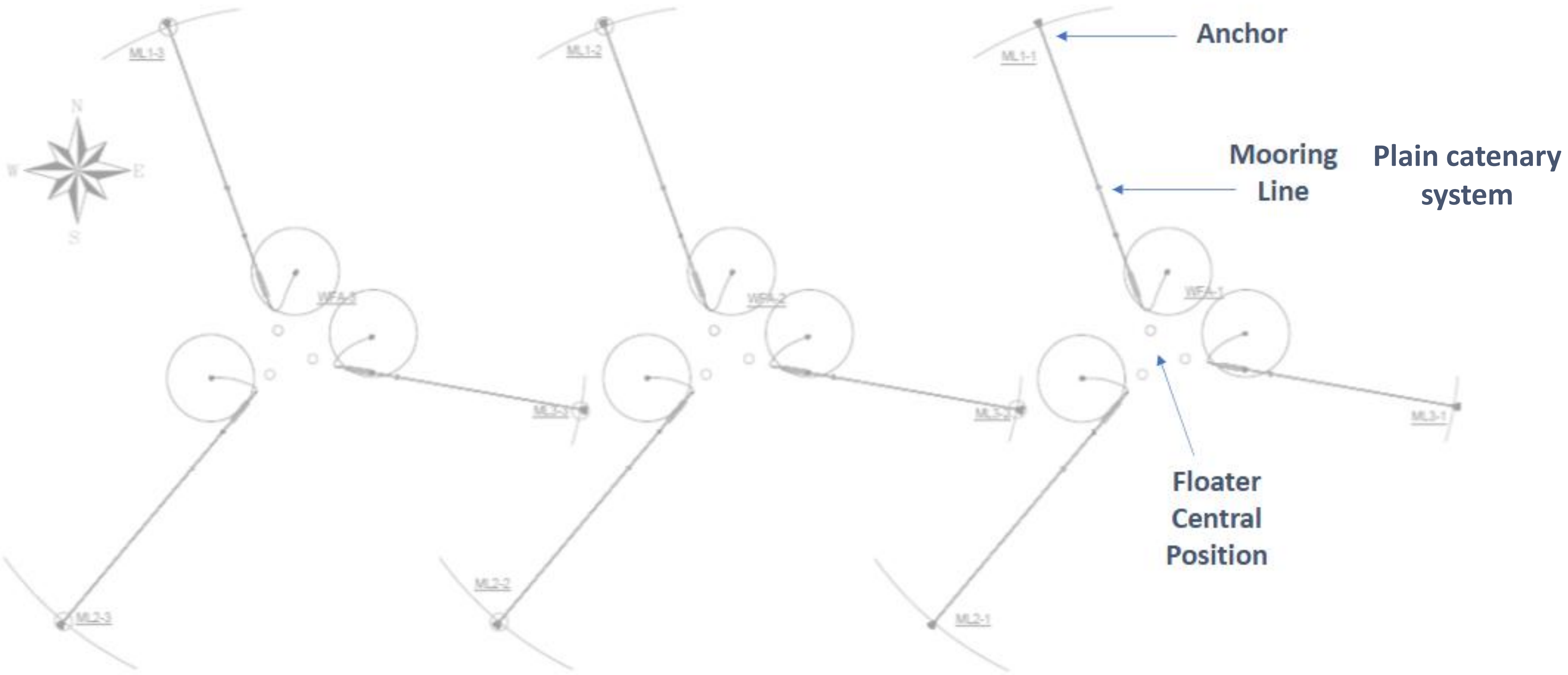
- The WFA project
- Overview



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- The WFA project
- Geophysical survey
  - Contractor: GEOxyz
  - Scope:
    - MBES
    - SSS
    - SBP
  - 2 potential areas

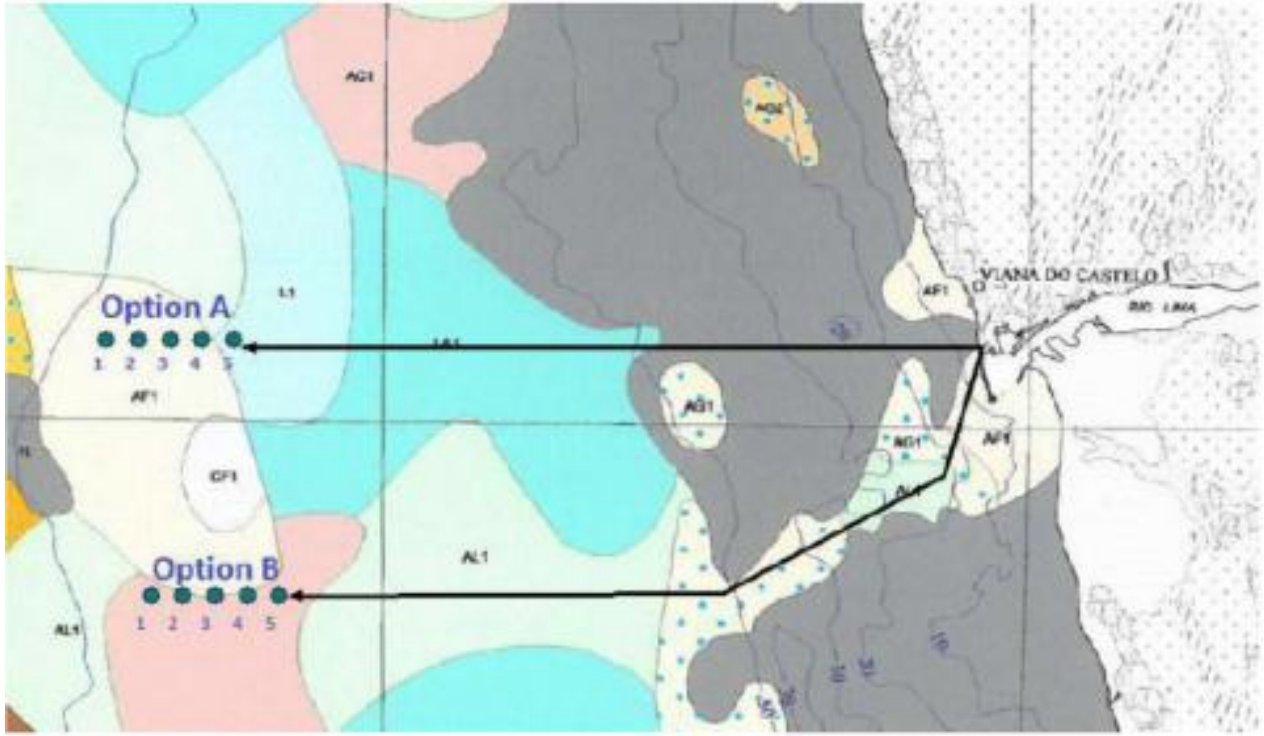

Figure 1: Possible locations for the Windfloat Atlantic

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- The WFA project
- Geophysical survey
  - Multibeam Echo Sounder
  - Bathy range 85 – 100m

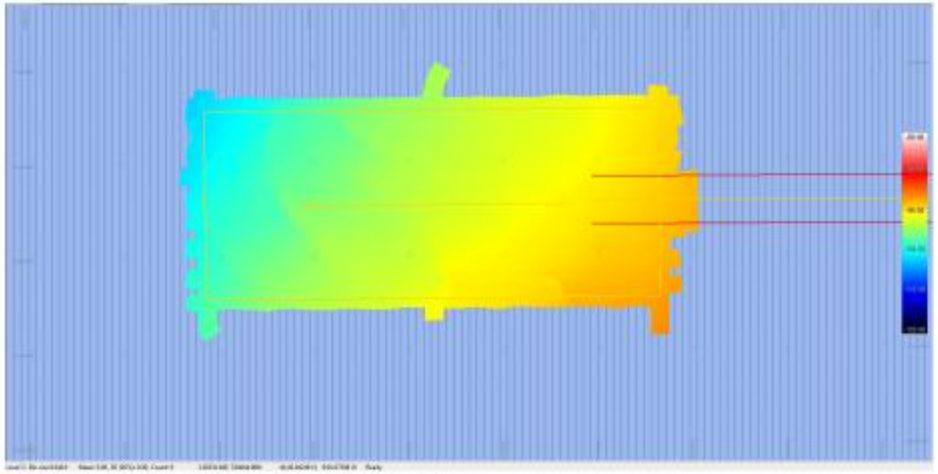

Figure 2 - Results of MB survey on Windfarm Zone A

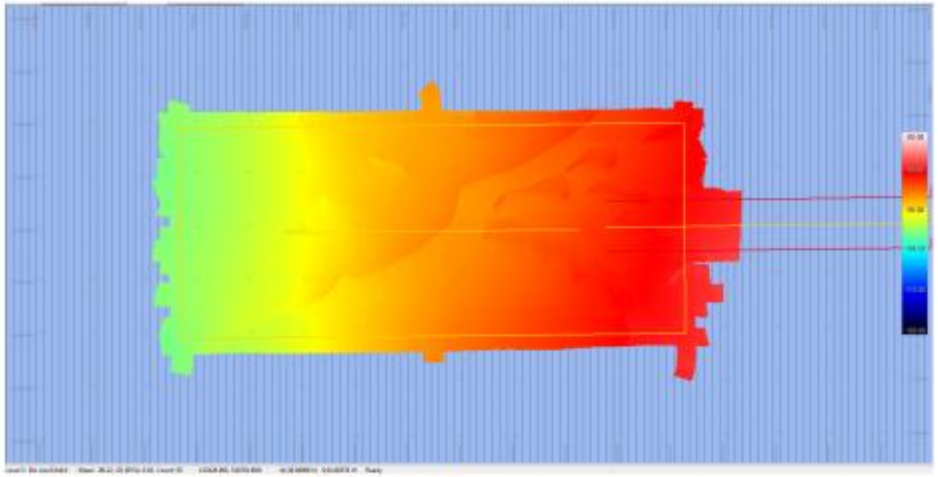

Figure 3 - Results of MB survey on Windfarm Zone B

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- The WFA project
- Geophysical survey
  - Side Scan Sonar
  - Hard layer > 20m

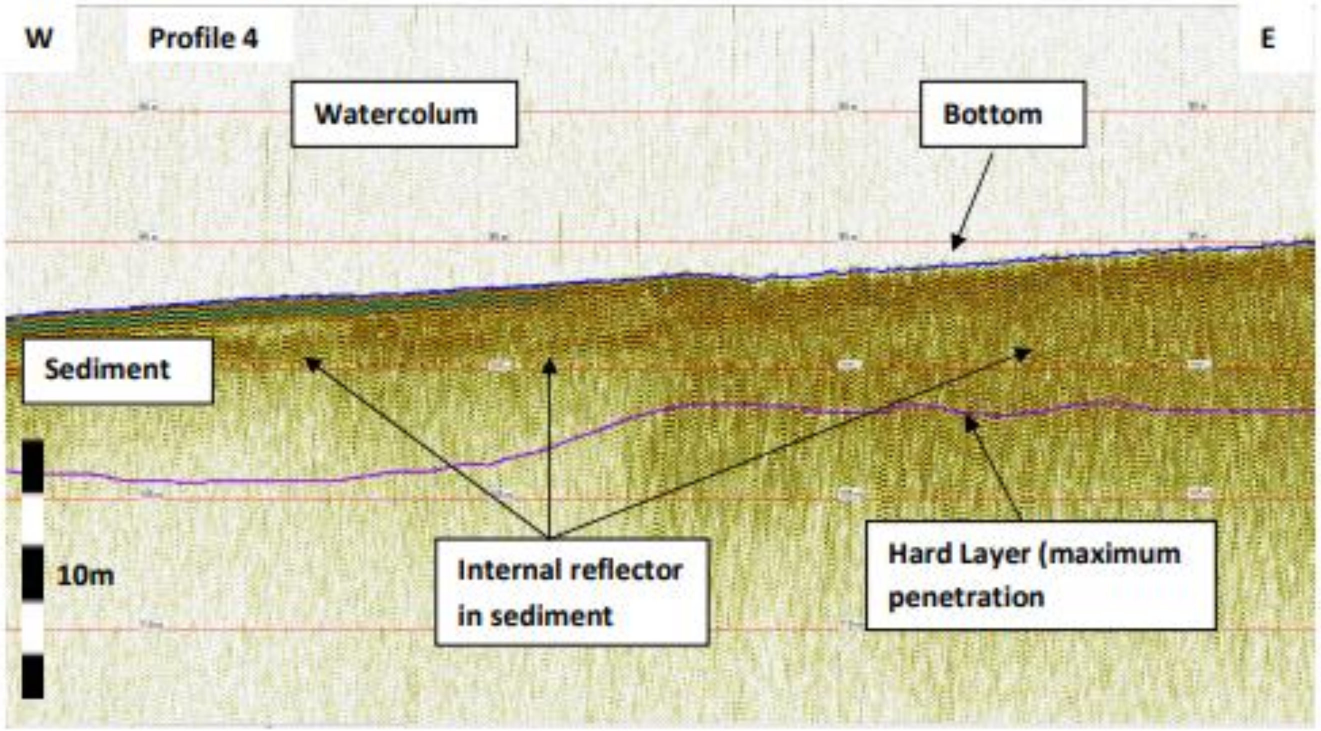

Figure 8 - Example profiles in Zone A & Zone B - horizontal scale: 1000m

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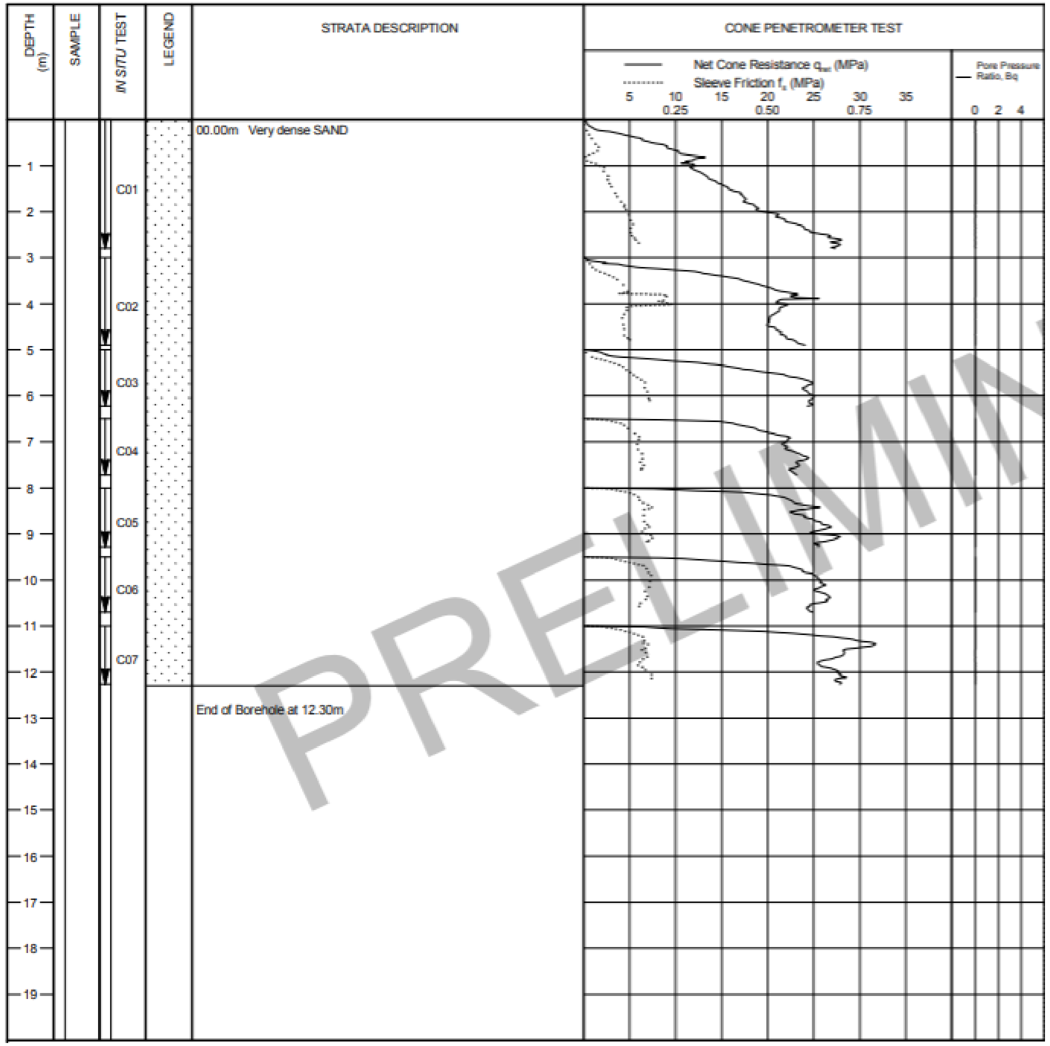
- The WFA project
- Geotechnical survey
  - Contractor: Geoquip Marine
  - Scope:
    - 2 continuous DtH-CPTu (12m)
    - 1 continuous BH sampling (15m)
    - Lab testing
  - Homogenous medium to very dense sand profile



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- The WFA project
- Anchor selection
  - Vryhof carried out an anchor feasibility assessment
  - SSS revealed higher potential seabed features (potential obstructions) in Zone B
  - Uniform sediment cover across the site
  - Geotech soundings not carried out at anchor locations – conservative assumptions and design (small scale project)
  - Loads within reasonable limits for DEA
  - Installation assessment is based on Vryhof experience and an anchor suited for penetration in hard conditions was considered
  - Anchor was ballasted internally and equipped with cutter points

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- The WFA project
- Installation
  - Mooring Pre-Lay





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- The WFA project
- Installation
  - Mooring hook-up

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- The WFA project
- Installation
  - Mooring hook-up

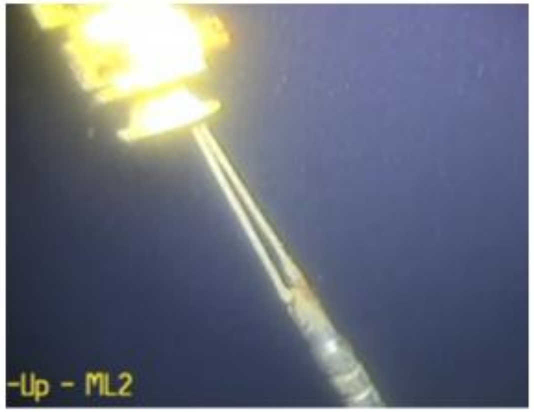
1. Stabilize the tow in position

2. Board the unit

3. Route onboard winch rope

4. Retrieve winch rope with ROV & connect subsea

5. Pull using onboard winch



6. Mooring connector automatically locks

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CONCLUSIONS

- The Ground Engineering cycle is the process leading to anchor selection, design and installation
- The Ground Model and GIR are evolving documents, starting with the Desktop study and finishing with Year 2 campaigns
- Geophysical campaigns provide a full coverage of the site, correlation with geotechnical data provides insight on soil behaviour and parametrization
- At commercial scale projects these are divided in Year 1 and 2, with different objectives each
- Anchor selection is based on several factors, including water depths and soil conditions
- The WFA is one of the first floating pre-commercial projects in the world, the first wind farm with semisubmersible technology
- Geophysical and geotechnical campaigns were carried out, not necessarily considering anchor locations
- DEA were the anchors type selected both in terms of cost-effective design and installation

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