Geophysical – Geotechnical Ground data Integration and Interpretation.

Integration and interpretation of Geophysical and Geotechnical data for offshore wind development de-risking.

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OUR COMPANY

SUMMARY

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BUSINESS LINES

Environment and Sustainability Consulting

Marine Survey

Laboratory Testing & Inspection

INDUSTRIES WE SERVE

Renewable Energy

Subsea Cables

Oil & Gas

Construction, Ports and Coasts

Multilateral and R&D Programs

OUR SHAREHOLDER

Tecnoambiente is a wholly owned company of the **Tradebe** Group.

760 M€ revenue
2800 employees
100% family business

OUR EXPERIENCE

40 years in business
Delivering offshore and onshore
350+ projects / year

THE TEAM

+ 150 employees
Average age of 41 years
9 languages spoken
43% of the team are women

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Site Characterization
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- Geotechnical Surveys
- UXO / Archaeological Campaigns
- Seismic Surveys (2D UHRS)

Construction & Maintenance
- Risk Management (UXO)
- Cable and Pipeline Inspections
- Infrastructure Inspections
- Decommissioning Support
- Dredging Operations Support

Geodata Report & Consulting
- Interpretation of Geophysical Data
- Interpretation of Geotechnical Data
- Integrated Model
- GIS Mapping and Technical Reports
- Specialized Consulting

ENVIRONMENT

Marine & Onshore Consulting
- Environmental Assessments (EIA)
- Environmental Monitoring Programs
- Biodiversity Habitat Restoration
- Project Permitting
- Stakeholder Management
- Analysis of Benthic Macrofauna
- Environmental Modelling
- Innovation and Development Projects
- Contaminated Soils (Onshore)
- Restoration, Wildfire and Emergency plans (Onshore)

Sustainability
- Climate Change
- ESG reporting
- Natural Capital
- Circular Economy
- Sustainable Finance

LABORATORY

Environmental Laboratory
- Water
- Waste
- Soils
- Sediments
- Compost
- Sludge
- Bioindicators
- Atmospheric Emissions

Waste characterization
- Macroscopic Characterizations
- Landfill Acceptance
- Compliance Testing
- Hazard Classification and EWC code

Specialized Consulting
- Environmental Monitoring
- Soil and Groundwater
- Environmental Construction Management
- Environmental Emissions and Noise

Concept & Feasability → **Design** → **Construction** → **Commissioning** → **Operations** → **Decommissioning**

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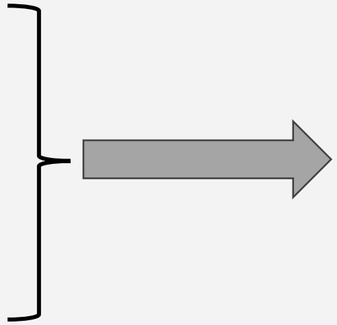
Webinar Presentation Summary

- **Part 1: Methodology**
  - Objectives and Available datasets
  - Methodology for data Integrations and Ground model development
  - Input data
  - Data limitations
  - Cross correlation process
  - Outputs
  - Deliverables
- **Sites investigated Overview**
  - BS
  - NAR
  - FOS
  - GLC
  - BNO
  - FGL



- **Sites presentation Summary**
  - Site overview
  - Available data
  - Seabed Condition overview
  - Geophysical and Geotechnical integration
  - Ground model
  - Geohazards
  - Key finding and risks

Objectives and Available Datasets

DGEC commissioned Tecnoambiente to integrate geophysical and geotechnical datasets and develop an initial ground model for offshore wind farm areas.

Datasets Integrated

Bathymetry (MBES), Acoustic imaging (SSS), Shallow geology (SBP), Deep geology (UHRS), UXO survey with ALARP assessment, Geotechnical survey (Composite boreholes, CPTs, Vibrocores, Piston cores and laboratory testing).

Main Deliverables

Integrated GIS database, Seismo-stratigraphic interpretation, Ground model, Geotechnical parameters for preliminary foundation design, and Geohazard assessment.

Key Outcome

Definition of Soil Units by combining geological, geophysical, and geotechnical information.
Definition of Soil Provinces by combining Seabed zones, soil units up to the depth of interest.

Methodology for Data Integration and Ground Model Development

Introduction:
The integration process aims to combine the spatial continuity of geophysical data with the ground-truth information provided by geotechnical investigations. The objective is to develop a consistent ground model that supports preliminary engineering design, identifies key ground risks, and highlights remaining uncertainties.

Data Sources:
The methodology starts with a review of all available datasets, including bathymetry, SSS, SBP, UHRS/seismic data, magnetometer or UXO information where available, boreholes, CPTs, vibrocores and laboratory test results. Each dataset is checked for coverage, resolution, datum, positioning, quality, and limitations.

The geophysical data are then interpreted to define seabed morphology, shallow geological structure, seismic facies, key reflectors,

Methodology for Data Integration and Ground Model Development

Data Integration:
The core of the integration is the cross-correlation between geophysical horizons and geotechnical ground truth. Borehole and CPT locations are projected onto nearby seismic lines, and soil changes observed in the geotechnical data are compared with seismic reflectors, acoustic facies and changes in seismic character. Where required, an assumed sound velocity is selected to convert seismic

Soil Unit Methodology:
Based on this correlation, the interpreted geological layers are grouped into engineering Soil Units. Each Soil Unit is defined by both its geophysical expression and its geotechnical behaviour, for example clay, dense sand, interbedded sand and clay, or very dense sand. Key horizons are then picked or adjusted to represent the top and base of each Soil Unit.

Once the Soil Units are defined, their regional extent is mapped across the survey area using the geophysical data. Horizon surfaces, isopachs and cross-sections are generated to show the lateral and vertical variability of the ground conditions. The resulting ground model provides a simplified but traceable representation of the shallow geology.

Methodology for Data Integration and Ground Model Development

Geotechnical Parameters:
Geotechnical parameters are then assigned to each Soil Unit using CPT data, laboratory testing and engineering judgement. Where appropriate, lower estimate, best estimate and higher estimate values are defined to reflect natural variability and data uncertainty.

Ground model utility:
Finally, the integrated ground model is used to identify ground-related risks and constraints, such as variable ground conditions, shallow gas, buried channels, sand waves, slopes, hard ground, boulders or UXO-related anomalies. The final outputs typically include an integrated GIS database, geological maps, interpreted profiles, Soil Unit descriptions, geotechnical parameter tables, geohazard maps and

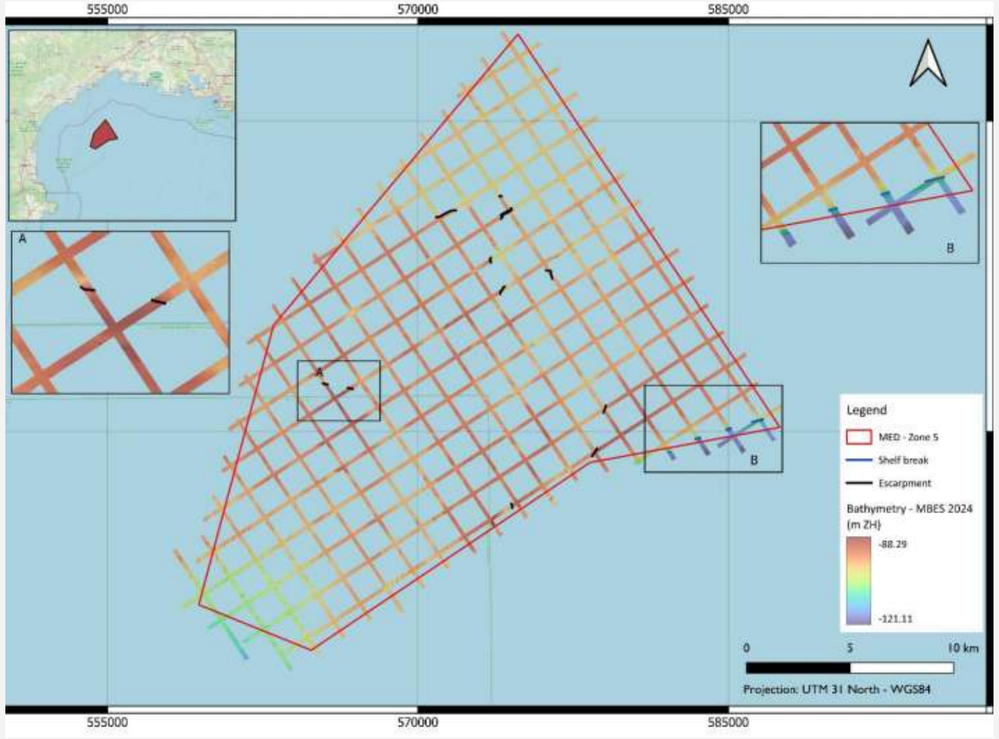
Input Data

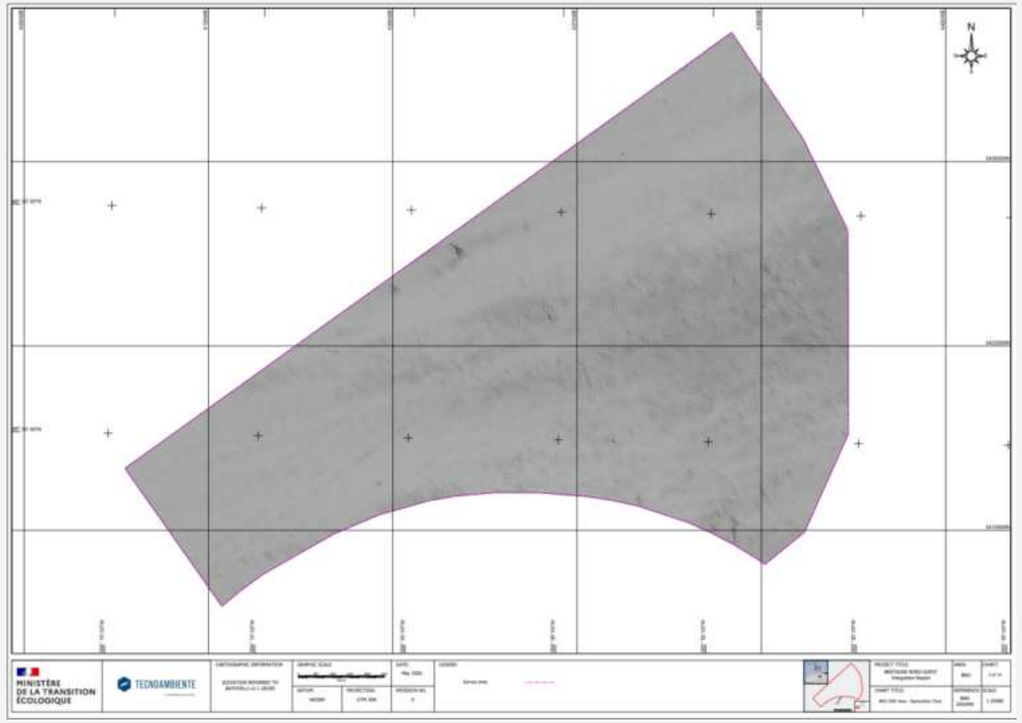
MBES bathymetry and slope

Side Scan Sonar - Backscatter

Boreholes, CPTs and laboratory testing

SBP and UHRS seismic data





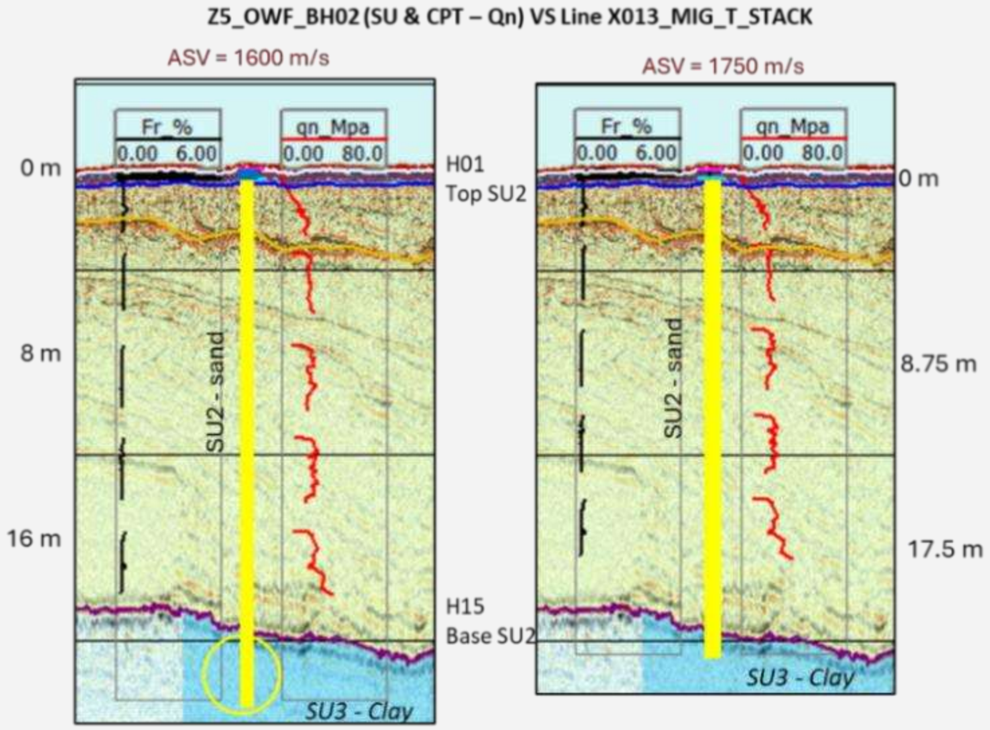
Input Data

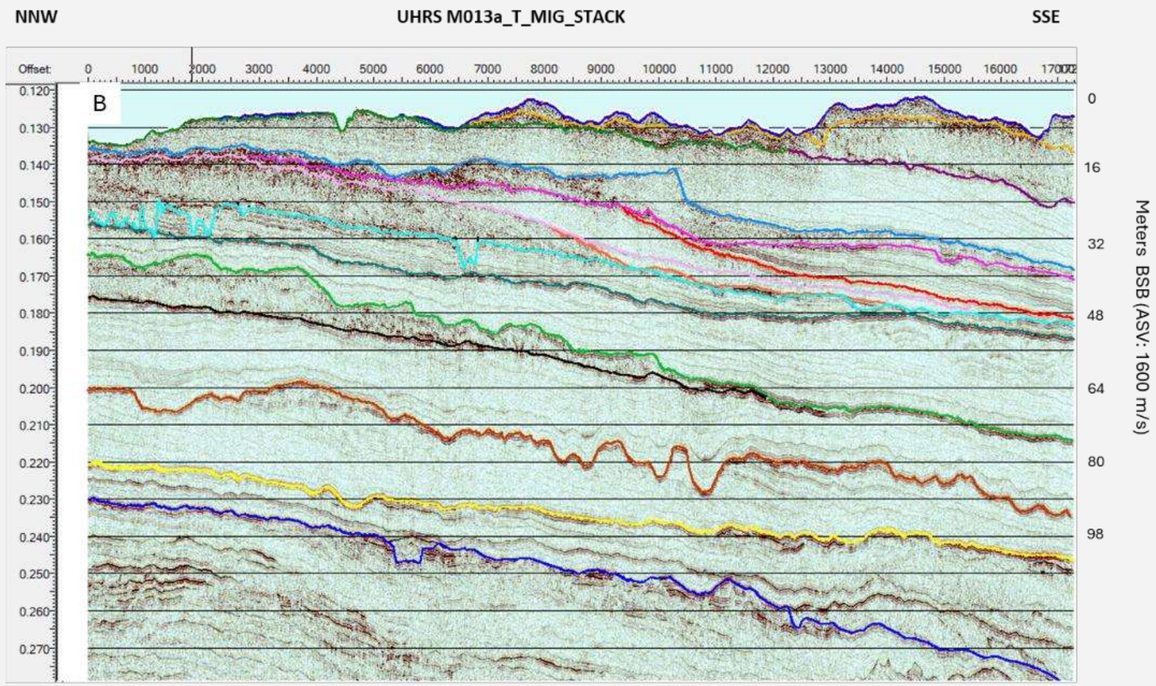
MBES bathymetry and slope

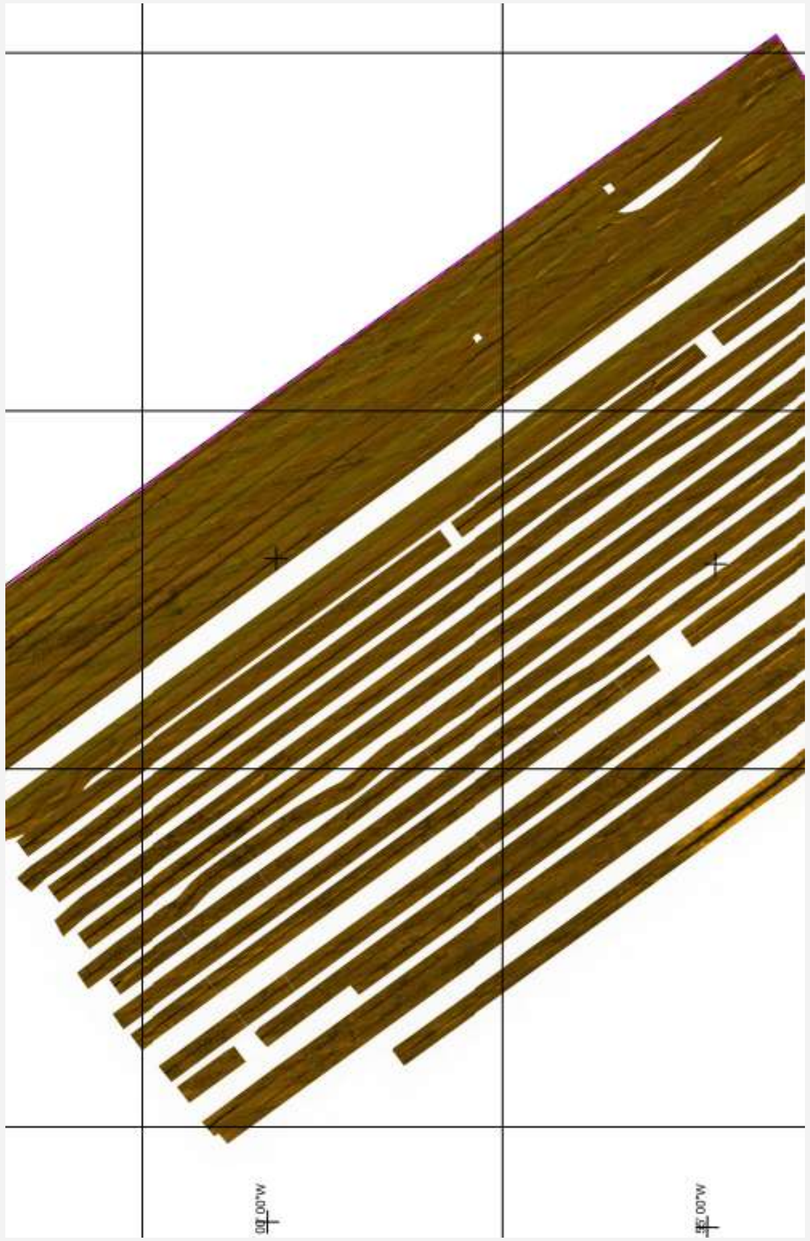
Side Scan Sonar - Backscatter

Boreholes, CPTs and laboratory testing

SBP and UHRS seismic data







Data Limitations

Before presenting the integration methodology and results, it is important to recognise the limitations associated with the available datasets. As is common in regional offshore site characterisation studies, the geophysical and geotechnical investigations were acquired with different objectives, spatial coverages and resolutions. The geophysical data provide extensive spatial coverage but require interpretation and extrapolation between survey lines, whereas the geotechnical data offer direct measurements of soil properties but are available only at discrete locations. Consequently, the integrated ground model represents the best interpretation of the available information at the time of reporting and should be considered as a regional-scale model intended for preliminary assessment and risk reduction. Areas of increased uncertainty and recommendations for further investigation have been identified where appropriate.

- Limited Geotechnical data
- Limited interpretation
- Wide UHRS/SBP spacing
- Partial Survey coverage

Cross-Correlation Process

Review & Validation

Analyze existing geophysical and geotechnical datasets.

Correlation

Align boreholes and CPTs with SBP and UHRS seismic facies.

Horizon Definition

Identify and define key seismic horizons.

Soil Unit Creation

Categorize units by geotechnical behaviour and seismic characteristics.

Model Generation

Interpolate horizons to generate the regional ground model.

Outputs

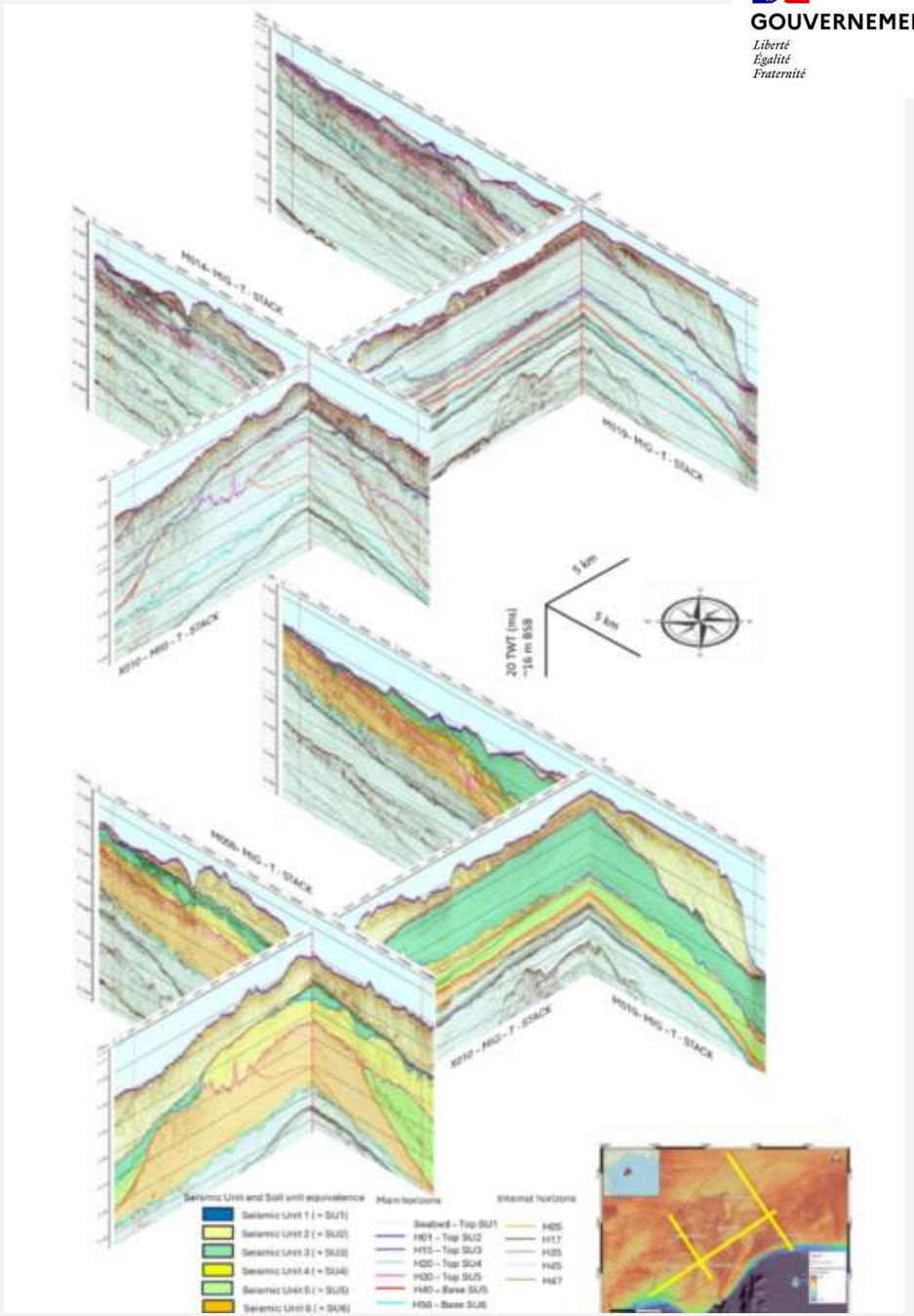
Soil Units and associated horizons

Ground model

Geotechnical parameter ranges

GIS deliverables and charts

Geohazard identification

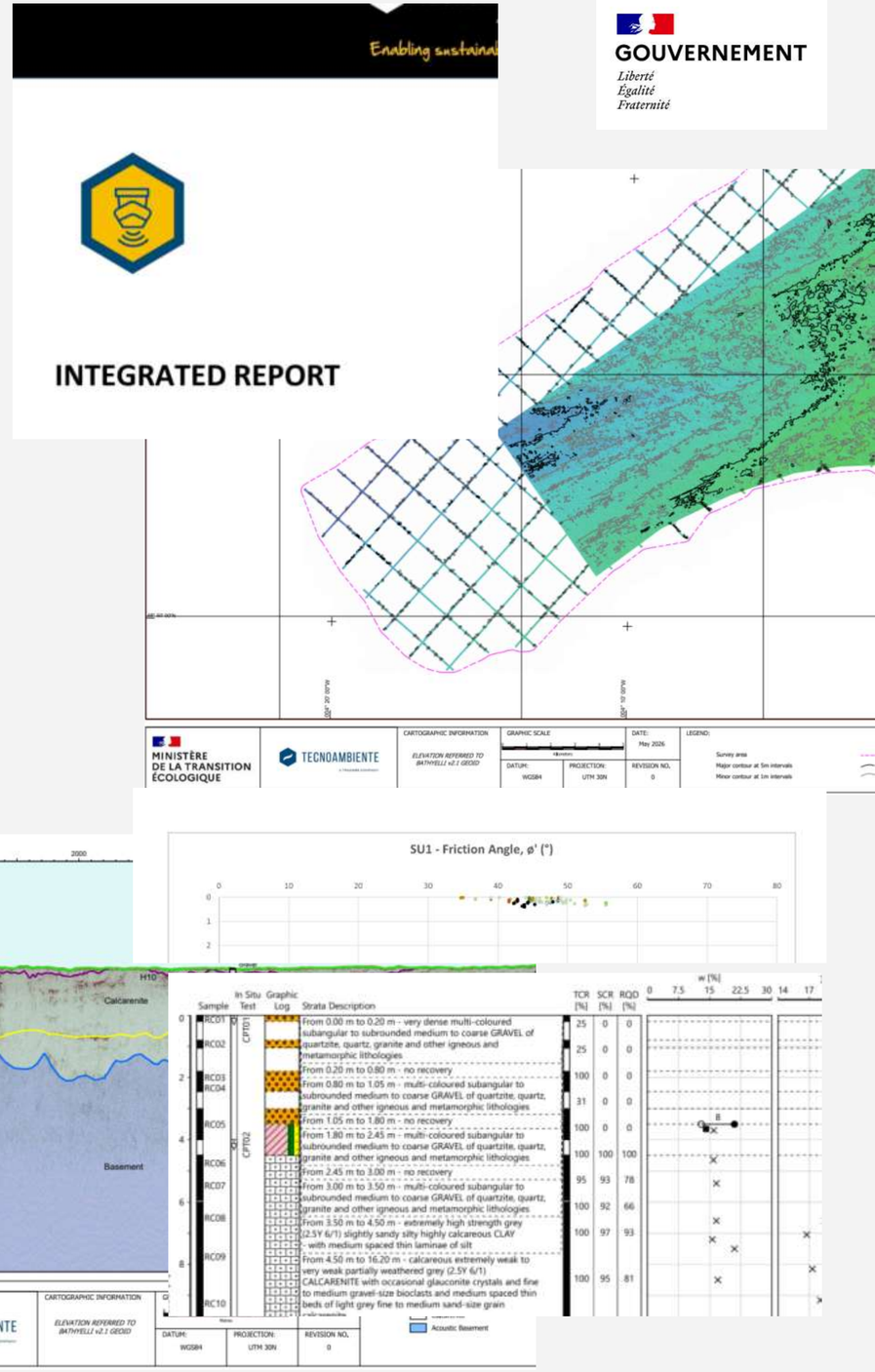


Deliverables

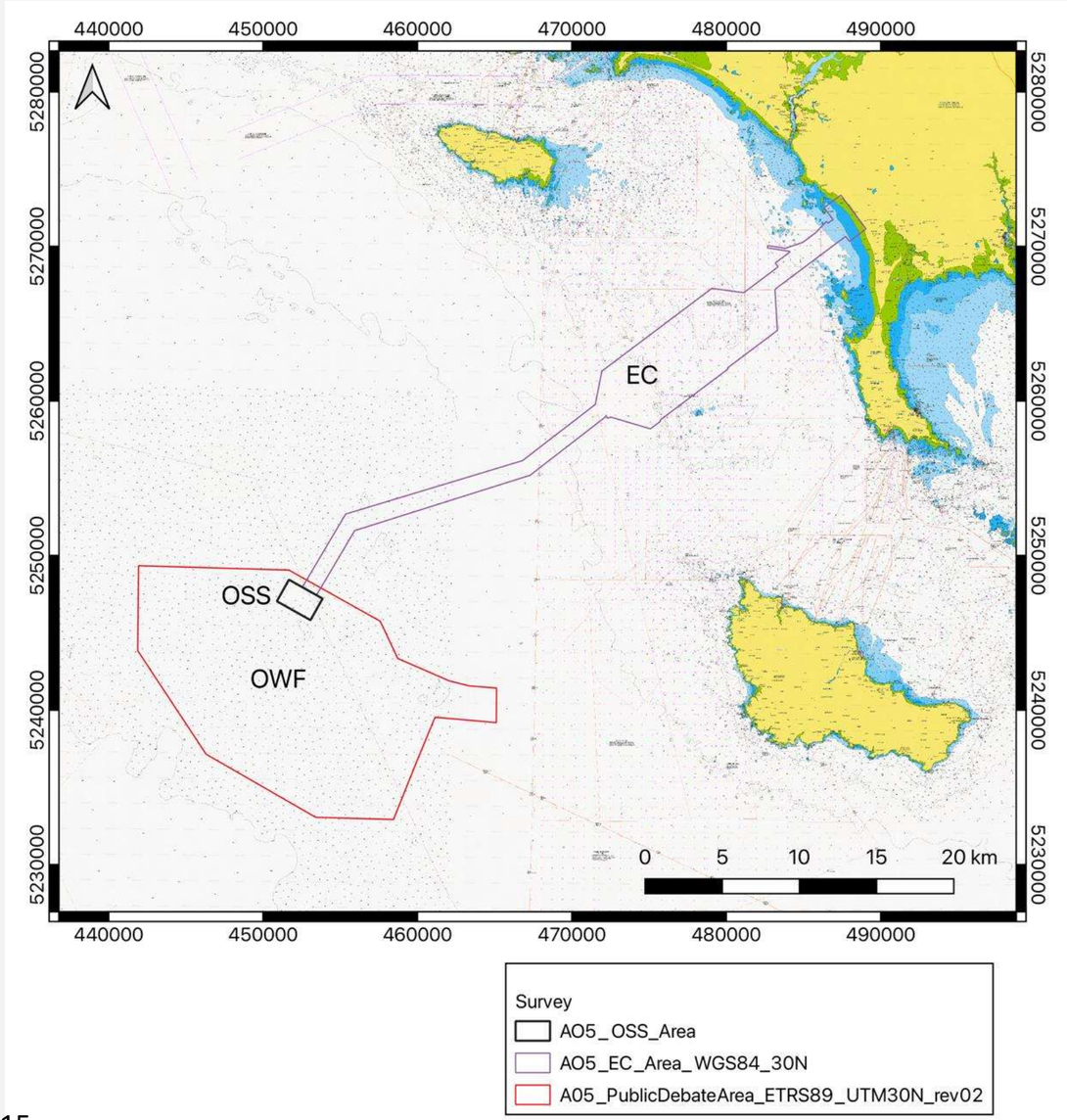
- Main Integrated Report (PDF)
  - Executive Summary
  - Seabed Conditions
  - Geological Framework
  - Soil Units
  - Ground Model
  - Soil Provinces
  - Geohazards Assessment
  - Recommendations

- Appendix A: 11 North-Up Charts (PDF + DWG)
- Appendix B: 3 UHRS Regional Profiles (PDF + DWG)
- Appendix C: Borehole Logs (PDF)
- Appendix D: Geotechnical Data Package
  - D1 Parameters Tables (PDF)
  - D2 Parameters Plots by Borehole (PDF)
  - D3 Parameters Plots by Soil Unit (PDF)
  - D4 Digital Data Package (XLSX, AFS, ASCII)

- GIS
  - Vector (Features) ARCGIS GDB
  - Raster ARC GIS GDB



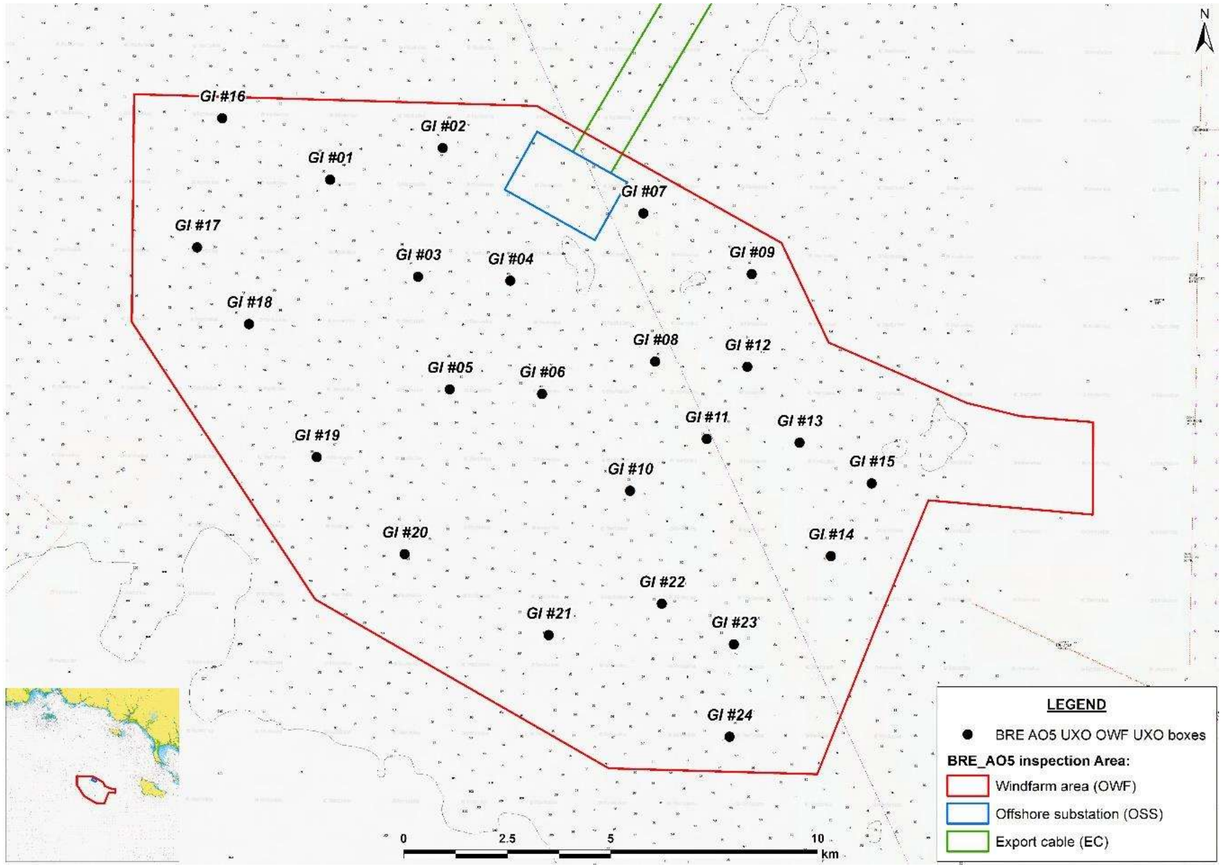
Bretagne Sud (BS)



- Located in the **Bay of Biscay**, approximately **20 km offshore Lorient (France)**
- Water depths ranging from 74 to 100 m ZH
- Area: approximately 232.8 km²
- site is located on the Armorican continental shelf and is characterized by:
- A thin veneer of **Plio-Quaternary sands, gravels and pebbles**
- Extensive outcropping and subcropping **Upper Cretaceous–Palaeocene carbonate bedrock**

Available Data

The data sources are organised into two categories: Geophysical and Geotechnical.



Geophysical

- MBES
- SSS
- SBP
- UHRS
- UXO

Geotechnical

- 14 Boreholes
- 14 CPT
- Rock coring
- Laboratory testing

Seabed Conditions

Overview of depth, slope, and geological characteristics

Water depth

Between 74 and 100 m.

Seabed slope

Generally <2º across the site with a maximum associanted to bedrock outcrops and escarpments

Bedforms

Localized sand waves, localized megaripples boulder fields, extensive rocky outcrops

Seabed morphology

Extensive rock-controlled seabed. Carbonate bedrock subcropping and outcropping at seabed. Local escarpments and rocky ridges. Boulder accumulations. Areas of thin sediment cover..

Anthropogenic features

Trawl marks locally observed, Isolated seabed objects detected,

Sediment distribution

Sand and Gravelly sediments,presence of pebbles Extensive limestone outcrops and localized dolomite outcrops. Marl

Key findings

Predominantly rock-controlled seabed morphology, Thin sediment cover across most of the site. xtensive limestone and dolomite subcrop/outcrop.

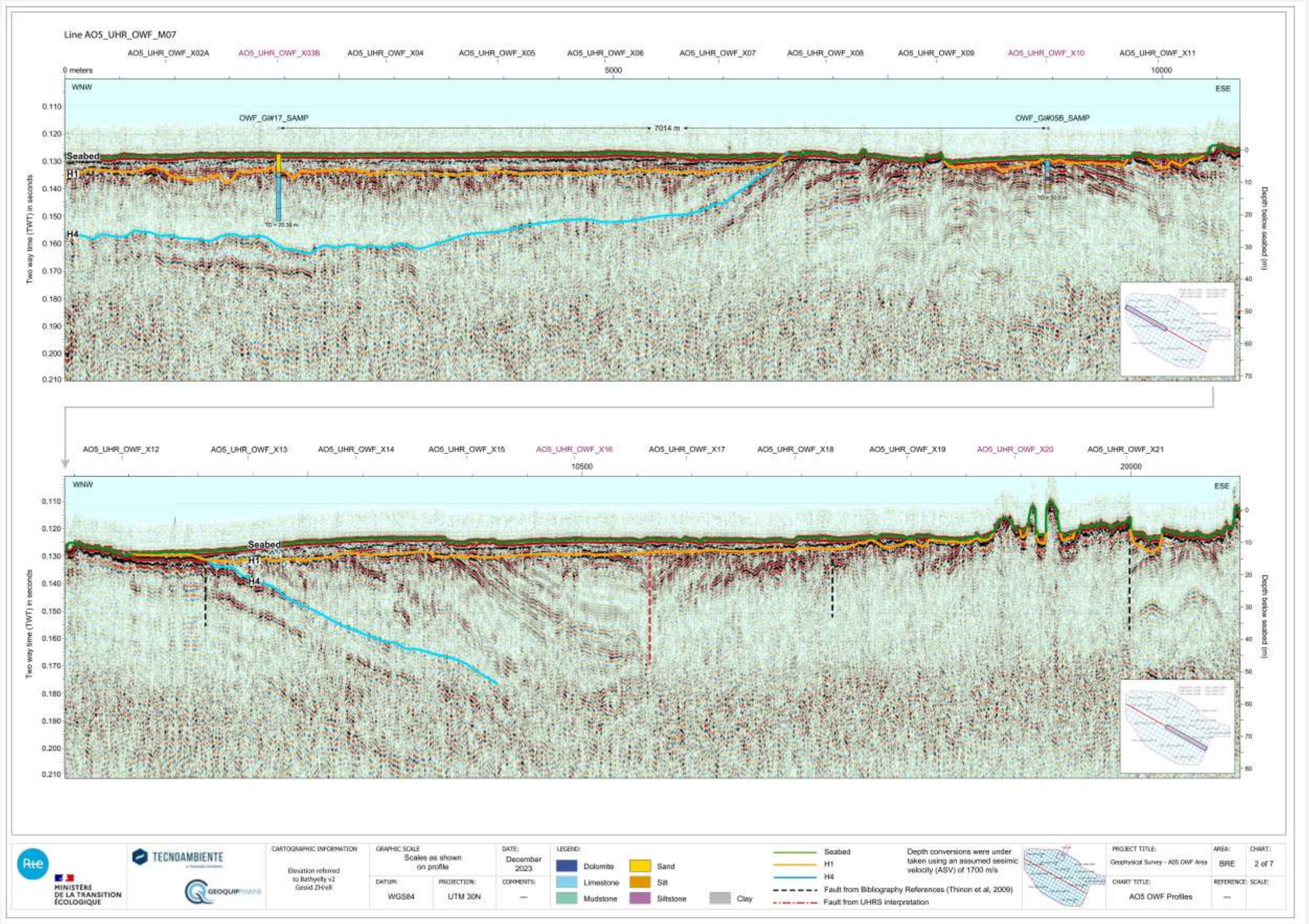
Geological and Geotechnical Integration

Correlation of and boreholes with UHRS and SBP profiles, identifying key seismic horizons and engineering Soil Units.

Geotechnical Unit	Engineering Soil Unit	Description	Engineering Behaviour
SAND	**SAND1**	Loose to medium dense sand	Moderate strength granular material
	SAND2	Dense sand with gravel and shell fragments	High friction angle and bearing capacity
DOLOMITE	**DOLOMITE**	Dolomitised carbonate rock	High strength rock unit with variable fracturing
LIMESTONE	**LIMESTONE**	Chalky to limestone bedrock	Dominant rock unit controlling foundation behaviour
MARL	**MARL1 – Clay**	Clay-rich marl	Low strength cohesive material
	MARL2 – Silt/Mudstone	Silty marl / mudstone	Moderate strength transitional unit
	MARL3 – Siltstone	Cemented marl / siltstone	Higher strength marl facies

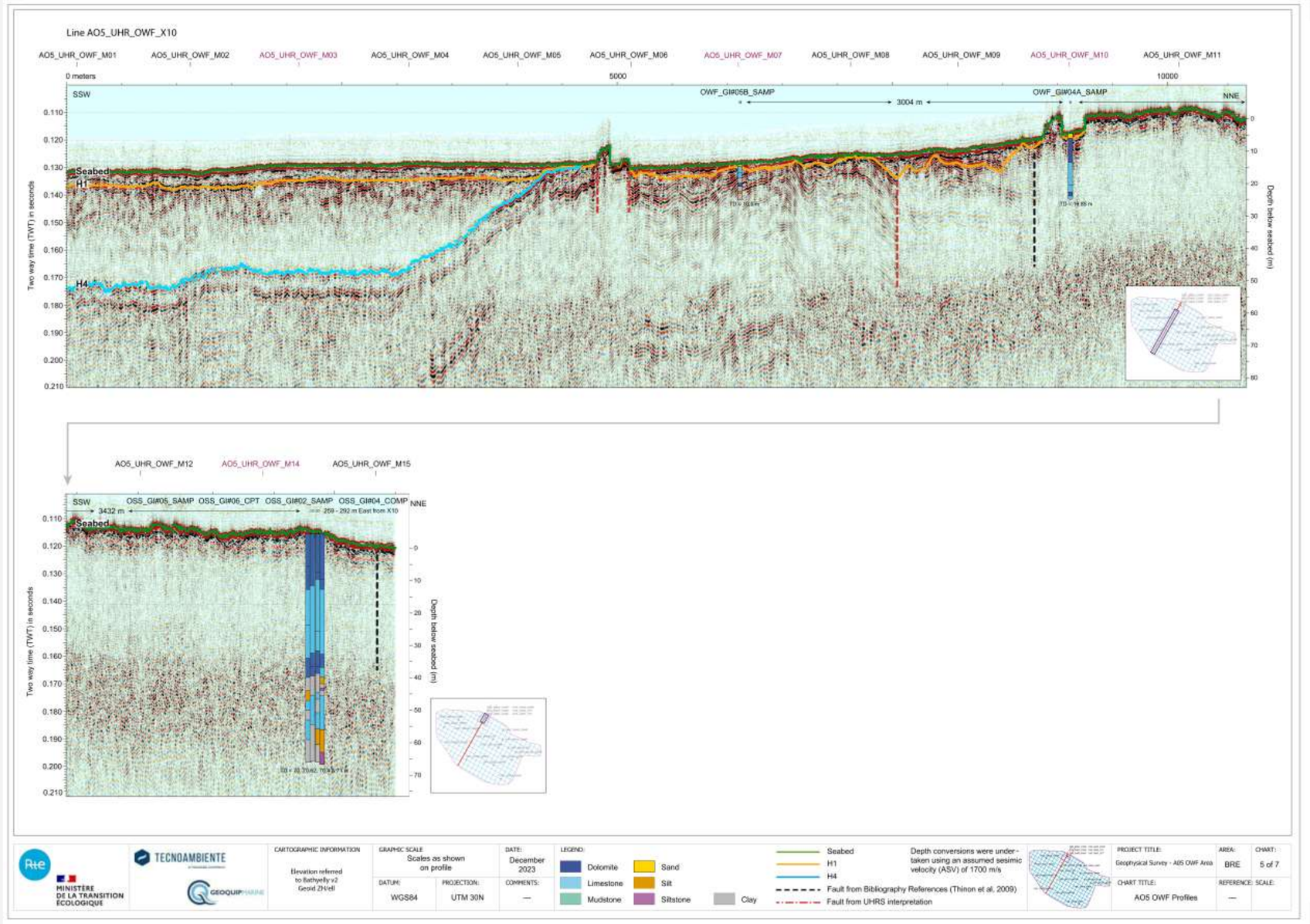
Ground Model

Correlated horizons identified.



Ground Model

Correlated horizons identified.



The BS2 ground model is characterized by a thin veneer of marine sands and gravels overlying shallow carbonate bedrock. Limestone forms the dominant geological unit across the site, with localized dolomite and marl intervals. Ground conditions are largely controlled by the depth, strength and fracturing of the carbonate formations rather than by sediment variability.

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Geohazards

Geohazard / Constraint	Risk Level	Observation	Potential Impact
Shallow Bedrock / Rockhead Variability	High	Limestone and dolomite frequently encountered at or near seabed.	Foundation selection, anchor penetration limitations and installation challenges.
Rock Strength Variability	High	Carbonate formations exhibit varying degrees of weathering, cementation and fracturing.	Uncertainty in pile drivability, drilling requirements and anchor capacity.
Boulder Fields	High	Numerous boulders and rock fragments identified from MBES and SSS data.	Local installation constraints and micrositing requirements.
Rock Outcrops & Escarpments	Moderate	Extensive carbonate outcrops and localized escarpments.	Cable routing and foundation positioning constraints.
Fractured Rock Zones	Moderate	Potentially fractured limestone and dolomite intervals identified.	May affect drilled pile performance and rock mass behaviour.
Thin Sediment Cover	Moderate	Sediment thickness generally 0–8 m.	Limited embedment opportunities for drag anchors or suction caissons.
Sand Waves / Megaripples	Low	Localized occurrence only.	Minor seabed mobility concerns.
Faulting	Low	No major active fault systems identified.	Limited engineering significance.
Shallow Gas	Low	No evidence of shallow gas accumulations.	Negligible risk.
Anthropogenic Objects / UXO	Low	Potential contacts investigated through dedicated surveys.	Local avoidance during detailed design.

Key Findings and Risks

Main Findings

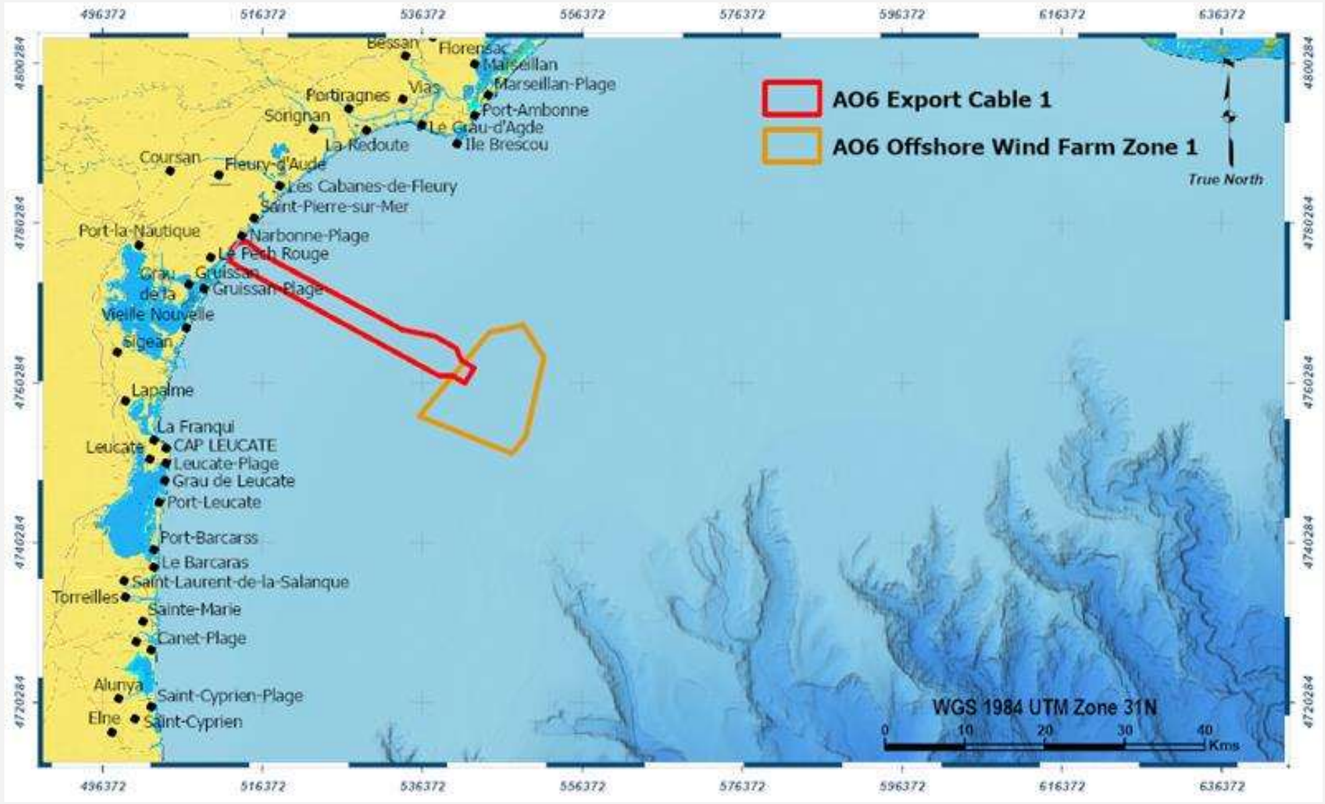
- Successful integration of **UHRS, SBP, MBES, SSS and geotechnical datasets** into a regional geological and geotechnical ground model.
- Identification of a **shallow-bedrock environment** dominated by carbonate formations.
- Definition of **7 Soil units**
- Bedrock is encountered at shallow depth across most of the site, typically beneath a thin veneer of sands and gravels.
- Geological conditions indicate that **rock-based anchoring solutions** are likely to be more suitable than sediment-dependent concepts.
- No major regional geohazards (active faulting, shallow gas or mass instability) were identified.

Main Uncertainties

- Carbonate Rock Variability
- Limited Rock Characterisation
- Geophysical Discrimination
- Shallow Bedrock
- Boulder Fields and Rock Outcrops
- **Fractured Rock Mass**

BS2 is a rock-dominated offshore wind site with generally favourable geological conditions. The primary uncertainty is associated with the variability and characterization of the carbonate bedrock, which will govern foundation selection, installation methods and detailed engineering design.

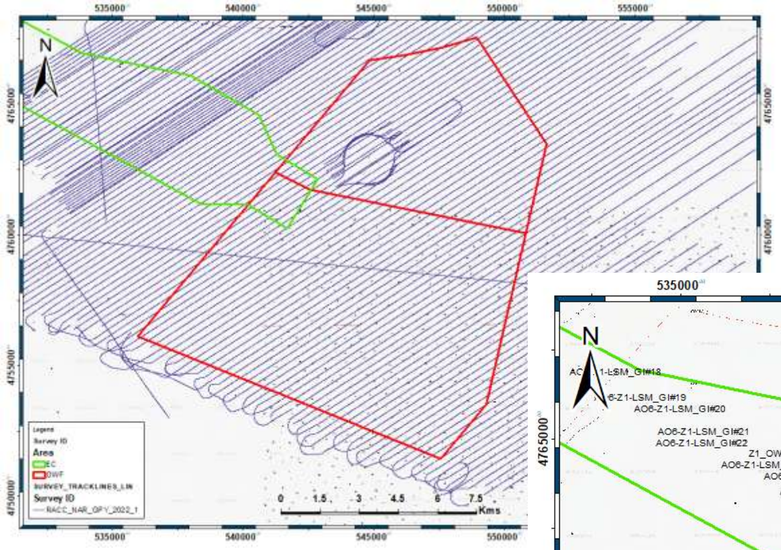
NAR

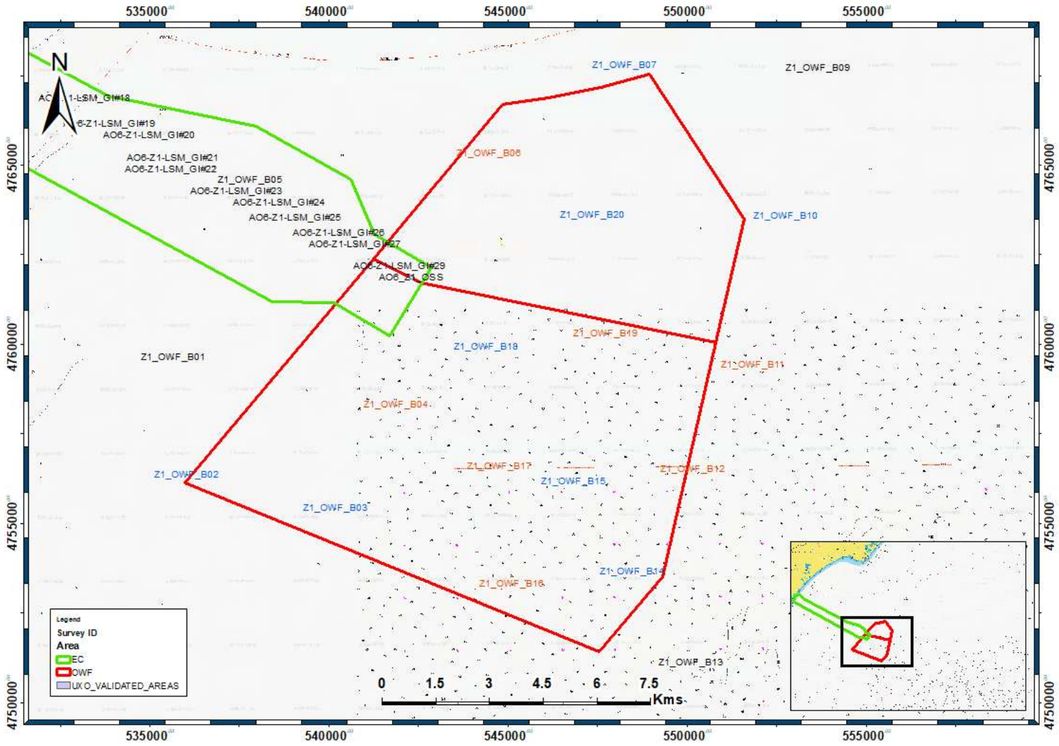


- Located in the Gulf of Lion ~37.4 km from Cap Leucate.
- Water depths ranging from 87 to 99 m ZH
- Area: approximately 144.7 km²
- Outer shelf marine environment dominated by silty-clayey deposits with localized sandy horizons and interbedded sand-clay sequences resulting from alternating depositional conditions
- **three main geotechnical units** and **six sub-units** within the first 30 m below seabed: .

Available Data

The data sources are organised into two categories: Geophysical and Geotechnical.





Geophysical

- MBES
- SSS
- SBP,
- UHRS
- UXO survey Box

Geotechnical

- 4 Piston cores,
- 12 Seabed CPT,
- 2 Vibrocores
- Laboratory testing offshore and onshore

Seabed Conditions

Overview of depth, slope, and geological characteristics

Water depth

Between 87 and 99.2 m.

Seabed slope

Generally low across the site.

Bedforms

Scour areas, Escarpments, seabed mounds and depressions

Seabed morphology

Areas of steep gradient, Scour features and escarpments, Seabed mounds, Depressions Local irregular seabed

Anthropogenic features

Isolated objects identified, trawl marks.

Sediment distribution

Predominantly Silt. Clay and Sand are present.

Key findings

Outer shelf marine environment dominated by fine-grained sediments

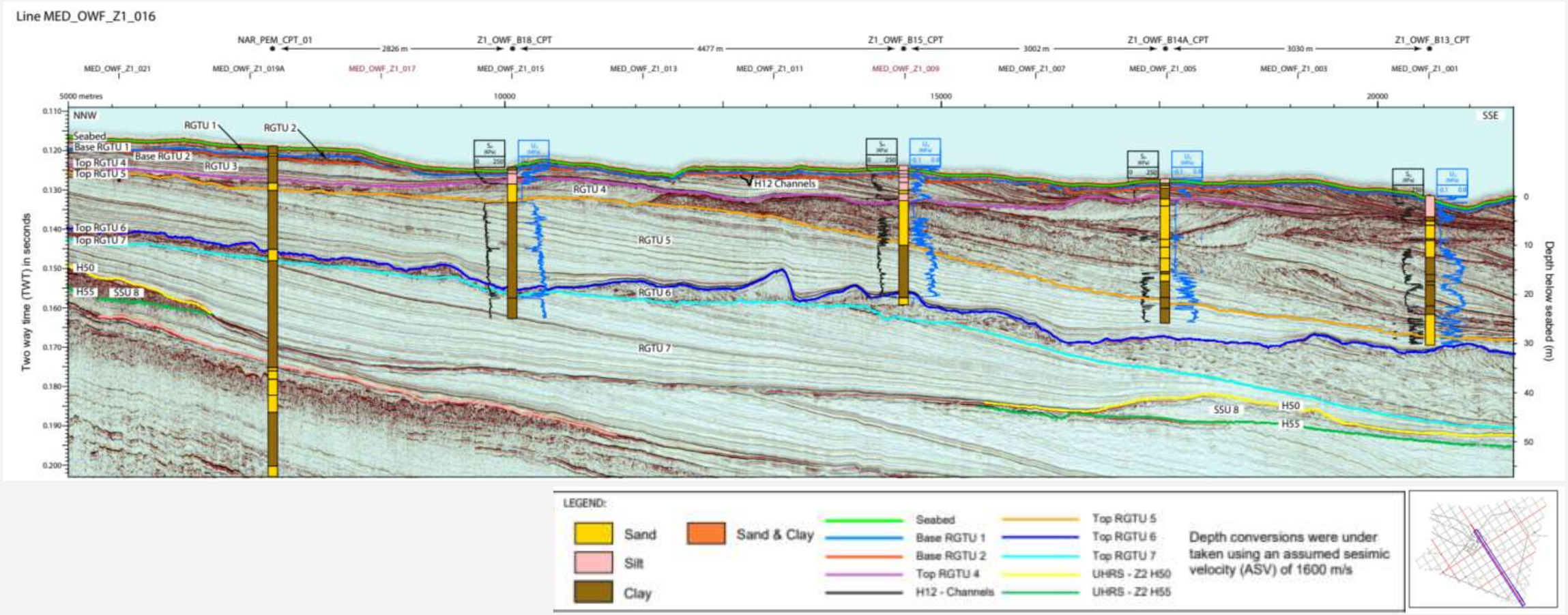
Geological and Geotechnical Integration

Correlation of and boreholes with UHRS and SBP profiles, identifying key seismic horizons and engineering Soil Units.

Soil Unit	General Description	Typical Engineering Behaviour
SILT1	Soft sandy clayey silt	Very low to low strength surficial deposits
SILT2	Sandy silt with occasional sand and clay interbeds	Low to moderate strength; variable stiffness
SAND1	Silty to clayey sand	Medium dense granular material
SAND2	Dense to very dense sand	High strength and stiffness
CLAY1	Sandy to silty clay	Low to moderate strength cohesive soil
CLAY2	Clay with local sandy horizons	Moderate to high strength cohesive deposits

Ground Model

Correlated horizons identified.



Ground Model

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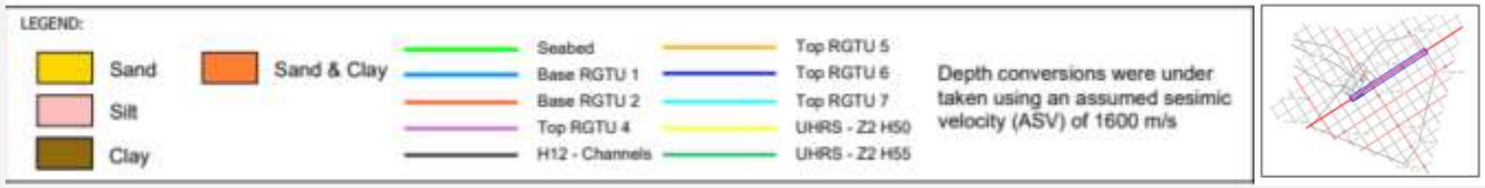
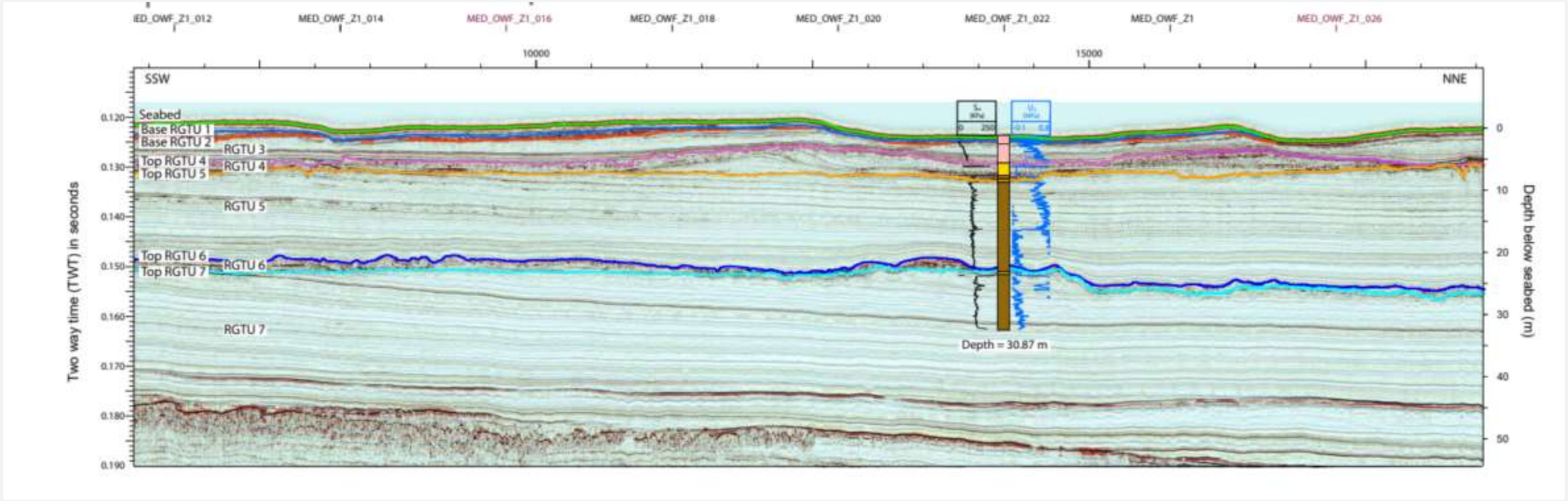




The NAR2 ground model is dominated by fine-grained marine sediments (silts and clays) with localized sandy horizons. Six engineering soil units were defined through the integration of UHRS, SBP, CPT and core data, providing the basis for preliminary floating wind anchoring and foundation assessments.

Geohazards

Geohazard / Constraint	Risk Level	Observation	Potential Impact
Variable Ground Conditions	High	Alternating silts, sands and clays across the site.	Spatial variability in anchor and foundation performance.
Scour Features & Escarpments	Moderate	Localized scour zones and escarpments identified in MBES data.	Local seabed instability and cable routing constraints.
Seabed Mounds	Moderate	Numerous seabed mounds interpreted across the area.	Potential local variations in seabed conditions and sediment thickness.
Depressions	Moderate	Local seabed depressions identified.	May influence foundation positioning and cable installation.
Steep Gradient Areas	Moderate	Isolated sectors with increased seabed slope.	Local installation and routing considerations.
Geological Faults	Low	Fault assessment completed; no major active structures affecting development identified.	Limited impact anticipated.
Potential UXO Contacts	Low	Contacts identified and managed through UXO investigation and clearance campaign.	Controlled through project mitigation measures.
Anthropogenic Objects	Low	Limited number of anthropogenic features detected.	Local avoidance during construction.
Mobile Bedforms	Low	No significant migrating sand-wave fields identified.	Low seabed mobility risk.
Shallow Gas	Low	No major shallow gas hazard reported within the integrated interpretation.	Low geotechnical risk.

Key Findings and Risks

Main Findings

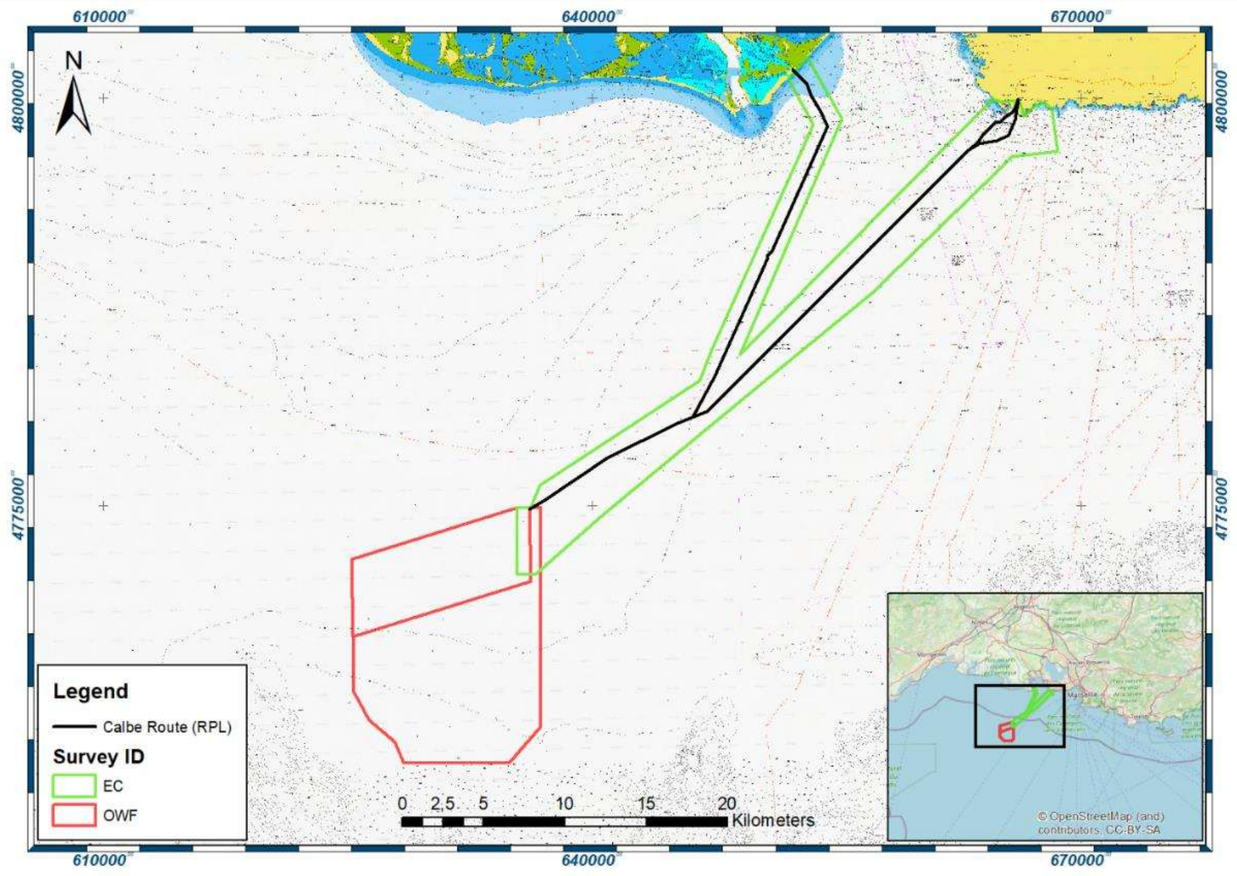
- Successful integration of **UHRS, SBP, MBES, SSS, UXO and geotechnical datasets** into a unified ground model.
- Site characterized by a predominantly **marine shelf sedimentary environment** composed of silts, sands and clays with localized interbedded sequences.
- Bathymetry is relatively uniform (**87–99 m ZH**) with limited relief and no major geological constraints identified
- Ground model suitable for **preliminary floating wind anchoring and foundation design studies**.

Main Uncertainties

- **Limited geotechnical coverage** relative to the size of the development area (144.7 km²)
- **Complex geological setting** resulting in lateral variability of sediment thicknesses and soil properties across the site
- Ground-truthed **soil types may only be extrapolated within approximately 500 m** of investigation locations.
- Derived **geotechnical parameters are considered representative only within approximately 100 m** of investigation points

NAR2 presents generally favourable conditions for floating offshore wind development, with a well-defined regional geological framework and limited major geohazards. The main remaining uncertainty is the spatial variability of sediment properties between geotechnical investigation locations, which should be refined through future site-specific investigations.

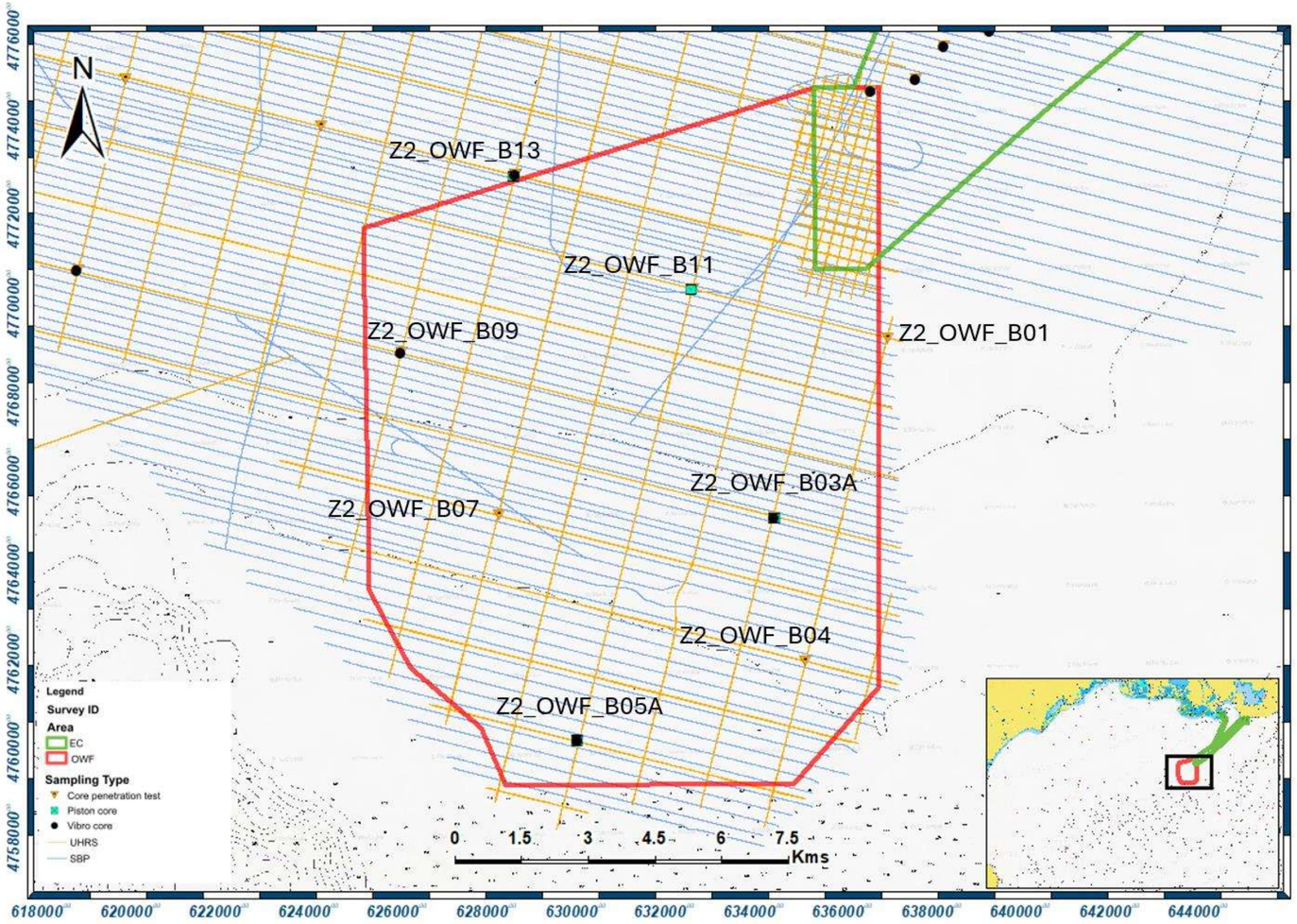
FOS



- Located in the Gulf of Lion offshore Marseille.
- Water depths ranging from 71 m to 128 m ZH
- Area: approximately 311.72 km²
- Sedimentary environment dominated by alternating silts, sands and clays.
- Evidence of estuarine and marine depositional environments. Multiple erosional surfaces and channel features identified.
- Six Soil Units derived from the integrated seismic interpretation.

Available Data

The data sources are organised into two categories: Geophysical and Geotechnical.



Geophysical

- MBES
- SSS
- SBP,
- UHRS
- UXO survey Box

Geotechnical

- 4 Piston cores,
- 12 Seabed CPT,
- 6 Vibrocores
- Laboratory testing program Offshore and onshore (Static) Non dynamic, noncyclic)

Seabed Conditions

Overview of depth, slope, and geological characteristics

Water depth

Between 71 and 128 m.

Seabed slope

Generally low across the site.

Bedforms

Mega-ripples present locally

Seabed morphology

Gently sloping continental shelf.

Anthropogenic features

Two isolated objects identified, trawl marks.

Sediment distribution

Predominantly **silty clay and sandy silt** at seabed level.

Key findings

Evident channel features in bathymetric and seismic data

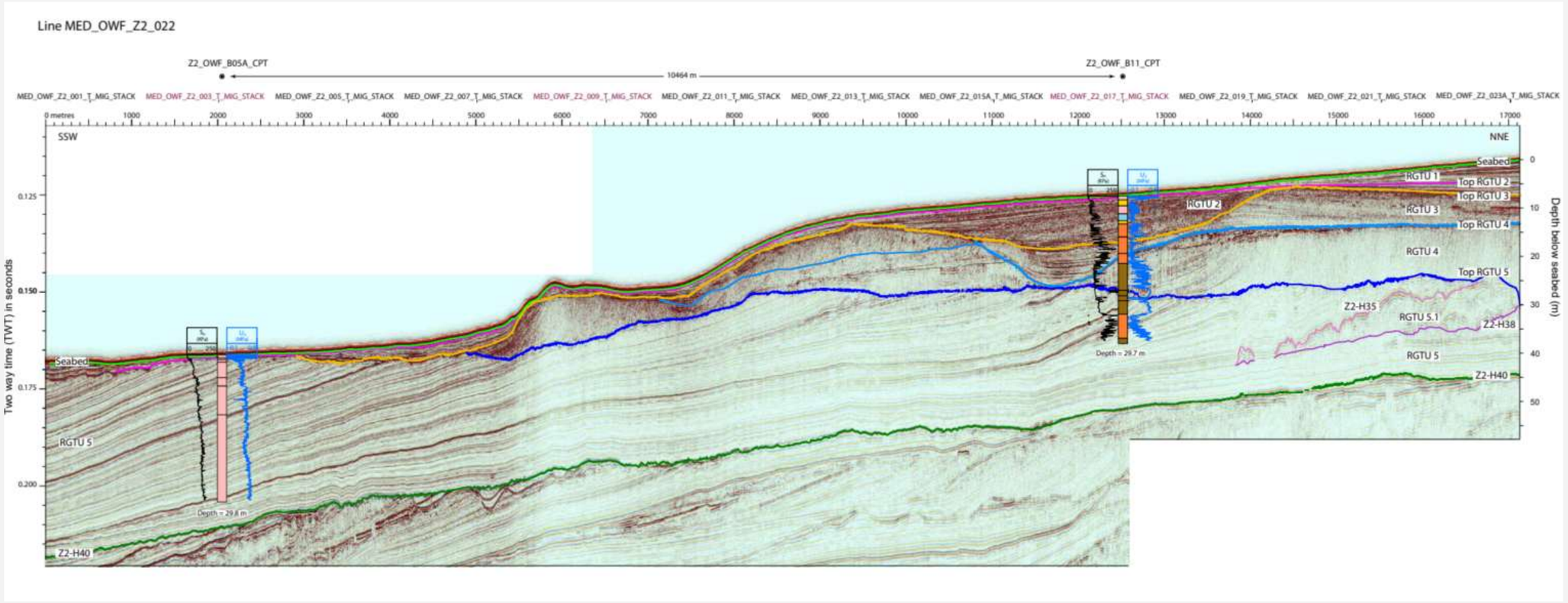
Geological and Geotechnical Integration

Correlation of and boreholes with UHRS and SBP profiles, identifying key seismic horizons and engineering Soil Units.

Soil Unit	General Description	Typical Engineering Behaviour
SILT1	Sandy clayey silt	Very low to low undrained shear strength; soft surficial deposits
SILT2	Sandy silt with local sand and clay interbeds	Low to moderate strength; variable behaviour
SAND1	Silty to clayey sand	Medium dense granular material
SAND2	Dense to very dense sand	High strength and stiffness; favourable foundation conditions
CLAY1	Sandy to silty clay	Low to moderate strength cohesive deposits
CLAY2	Clay with local sand/silt interbeds	Moderate to high strength cohesive deposits at depth

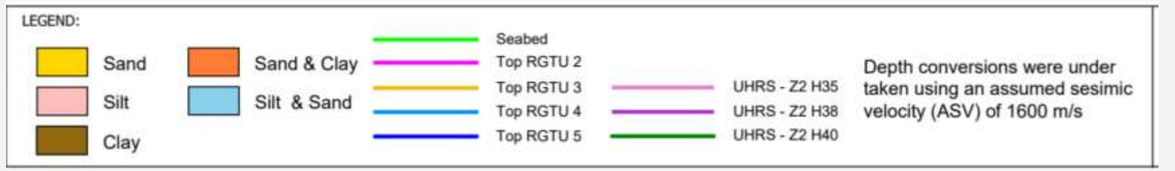
Ground Model

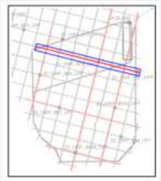
Correlated horizons identified.

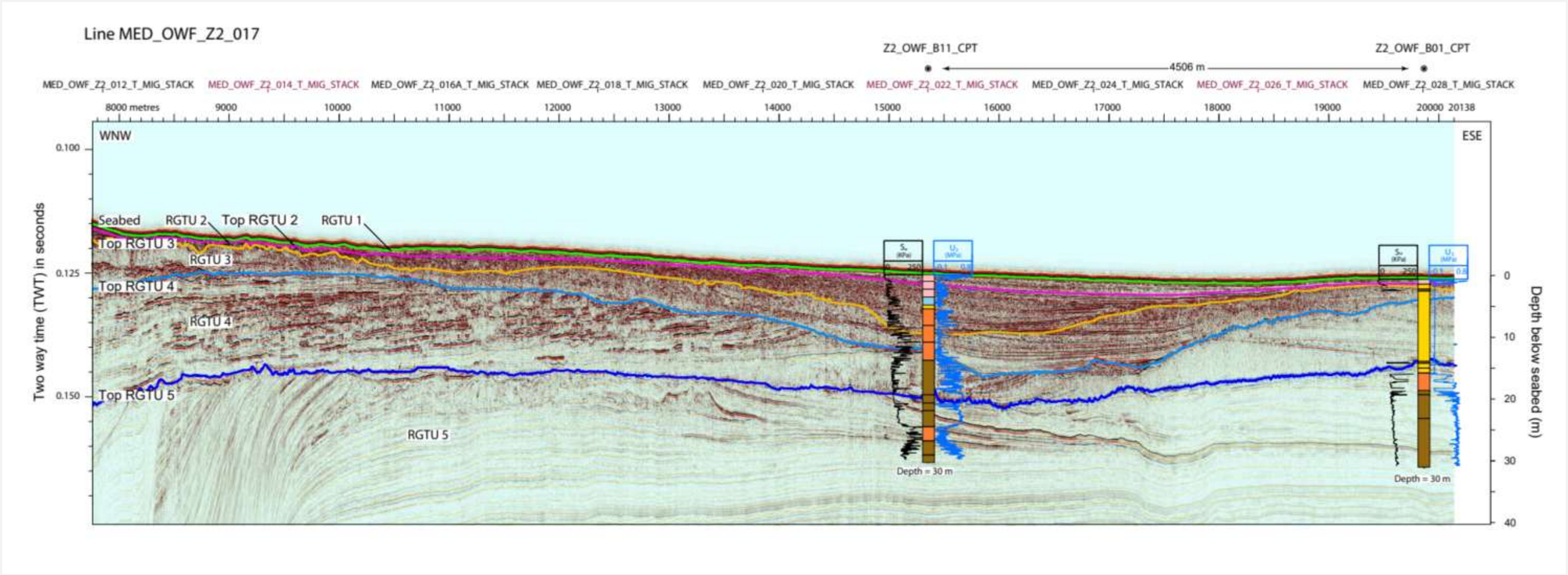


Ground Model

Correlated horizons identified.







The FOS2 ground model is characterized by alternating silts, sands and clays deposited in a complex marine and estuarine environment. Six engineering Soil Units were defined from the integration of geophysical and geotechnical datasets, allowing the derivation of representative design parameters for concept-level foundation assessments.

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Geohazards

Geohazard / Constraint	Risk level	Observation	Potential Impact
Variable Ground Conditions	High	Rapid lateral and vertical changes between silts, sands and clays.	Foundation performance variability and localized design adaptations.
Channel Systems	High	Multiple erosional and infilled channels identified in seismic data.	Variable sediment thicknesses and abrupt changes in soil properties.
Erosional Surfaces / Unconformities	High	Several regional erosional horizons identified.	Potential variability in bearing layers and anchor penetration depths.
Shallow Gas Indicators	Moderate	Localized acoustic anomalies interpreted as possible gas occurrences.	Additional investigation required prior to detailed design.
Mega-Ripples / Bedforms	Moderate	Local seabed bedforms observed in MBES data.	Potential seabed mobility and localized scour effects.
Seabed Depressions	Moderate	Localized depressions associated with sedimentary processes.	May influence foundation positioning and cable routing.
Slope Instability	Moderate	Local slopes associated with channel margins.	Site-specific stability assessment required.
Anthropogenic Objects	Low	Two isolated seabed objects identified.	Local avoidance during installation activities.
Trawl Marks	Low	Widespread evidence of fishing activity.	Minimal geotechnical impact but relevant for infrastructure planning.
Seismogenic Faulting	Low	No significant active faulting identified within the available datasets.	Low risk based on current interpretation.

Key Findings and Risks

Main Findings

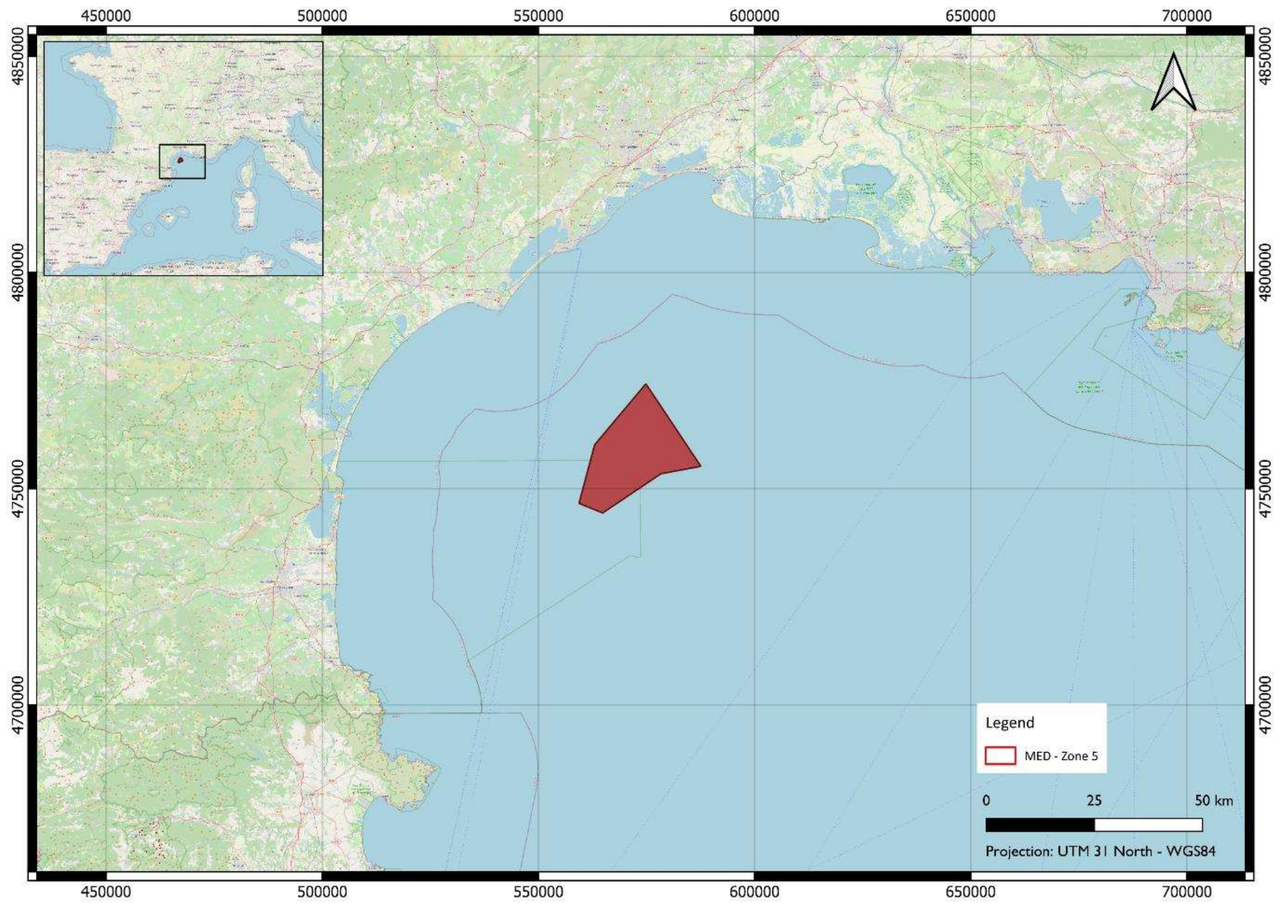
- Integrated interpretation of **UHRS, SBP, MBES, CPT, Vibrocore and Piston Core** datasets.
- Sediment-dominated site characterized by alternating: Silts, Sands and Clays.
- Identification of channel systems, erosional surfaces and dense sand bodies controlling subsurface variability.Geotechnical parameters derived to support concept-level design of floating offshore wind foundations and anchoring systems..

Main Uncertainties

- Limited geotechnical coverage
- Ground conditions and geotechnical parameters considered representative primarily within approximately **100 m** of investigation locations.
- Geological horizons can be extrapolated with caution up to approximately **500 m** from ground-truth locations
- Significant lateral variability associated with:
  - Channel systems
  - Erosional unconformities
  - Variable sand body distribution
- Localized shallow gas indicators require further assessment during detailed site investigations.

FOS2 presents generally favourable conditions for floating offshore wind development; however, the complex sedimentary architecture and channelized depositional environment result in significant spatial variability that should be refined through additional site-specific investigations during future project phases.

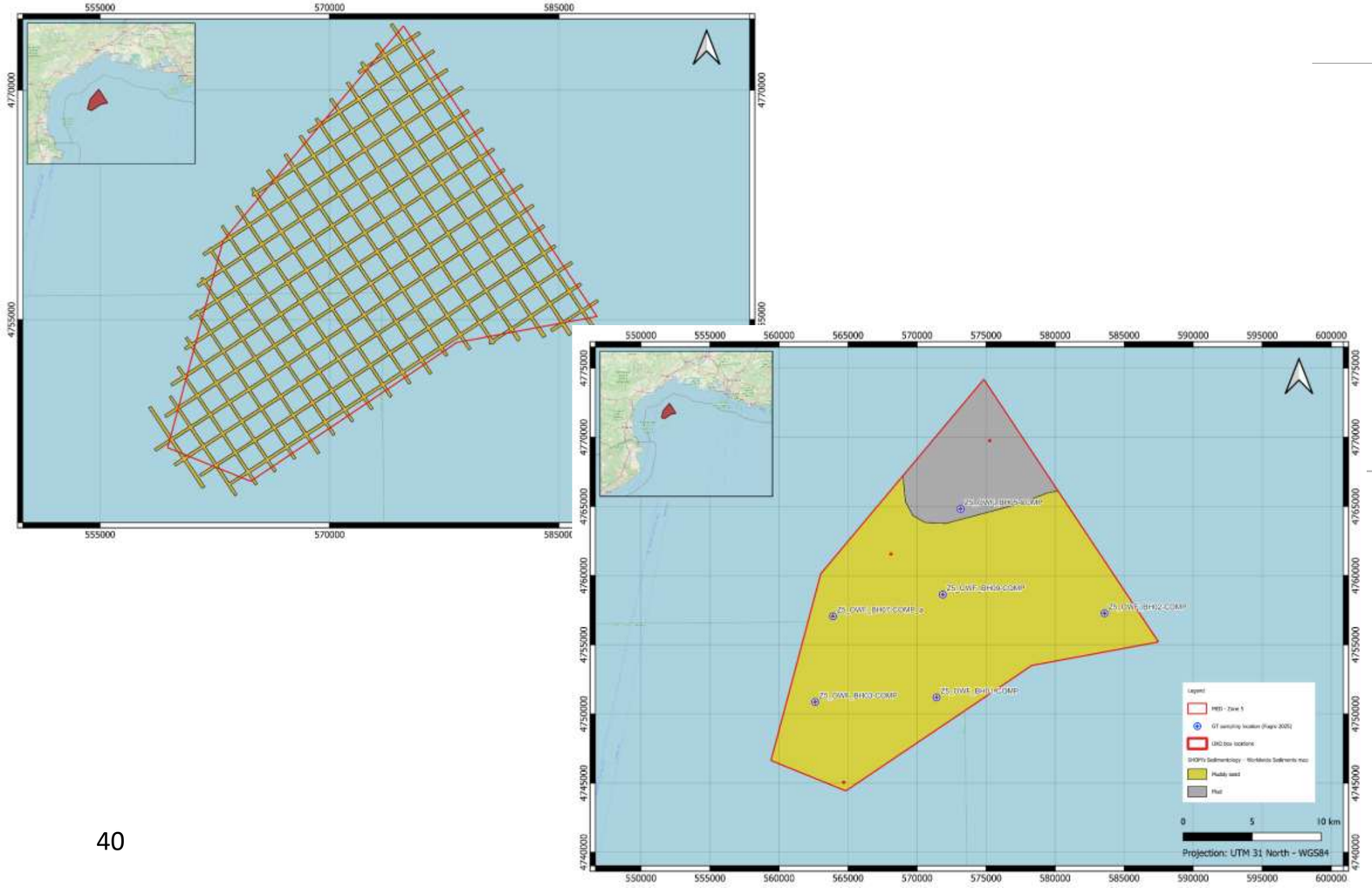
Golfe du Lion Centre (GLC)



- Located approximately 36 km offshore Agde
- water depths ranging from 88 m to 121 m ZH
- Area: approximately 399 km²
- Located close to the continental shelf break.
- Site characterised by relatively deep water and a sedimentary environment typical of the Gulf of Lion margin.

Available Data

The data sources are organised into two categories: Geophysical and Geotechnical.



Geophysical

- MBES
- SSS
- SBP
- UHRS
- UXO

Geotechnical

- 6 boreholes,
- CPT downhole,
- 42 offshore samples
- Laboratory testing program Offshore and onshore (Static) Non dynamic, non-cyclic)

Seabed Conditions

Overview of depth, slope, and geological characteristics

Water depth

Between 88 and 121 m.

Seabed slope

Average approximately 1.5°.

Shelf break

Located in the southeastern sector. Slope > 5º

Seabed morphology

Local canyons and depressions identified.

Anthropogenic features

Limited observations reported: 5 wrecks, trawl marks and anchor scars

Sediment distribution

Dominated by CLAY and SAND (no bedrocks). Buried channels.

Key findings

No major seabed constraints identified across most of the area.

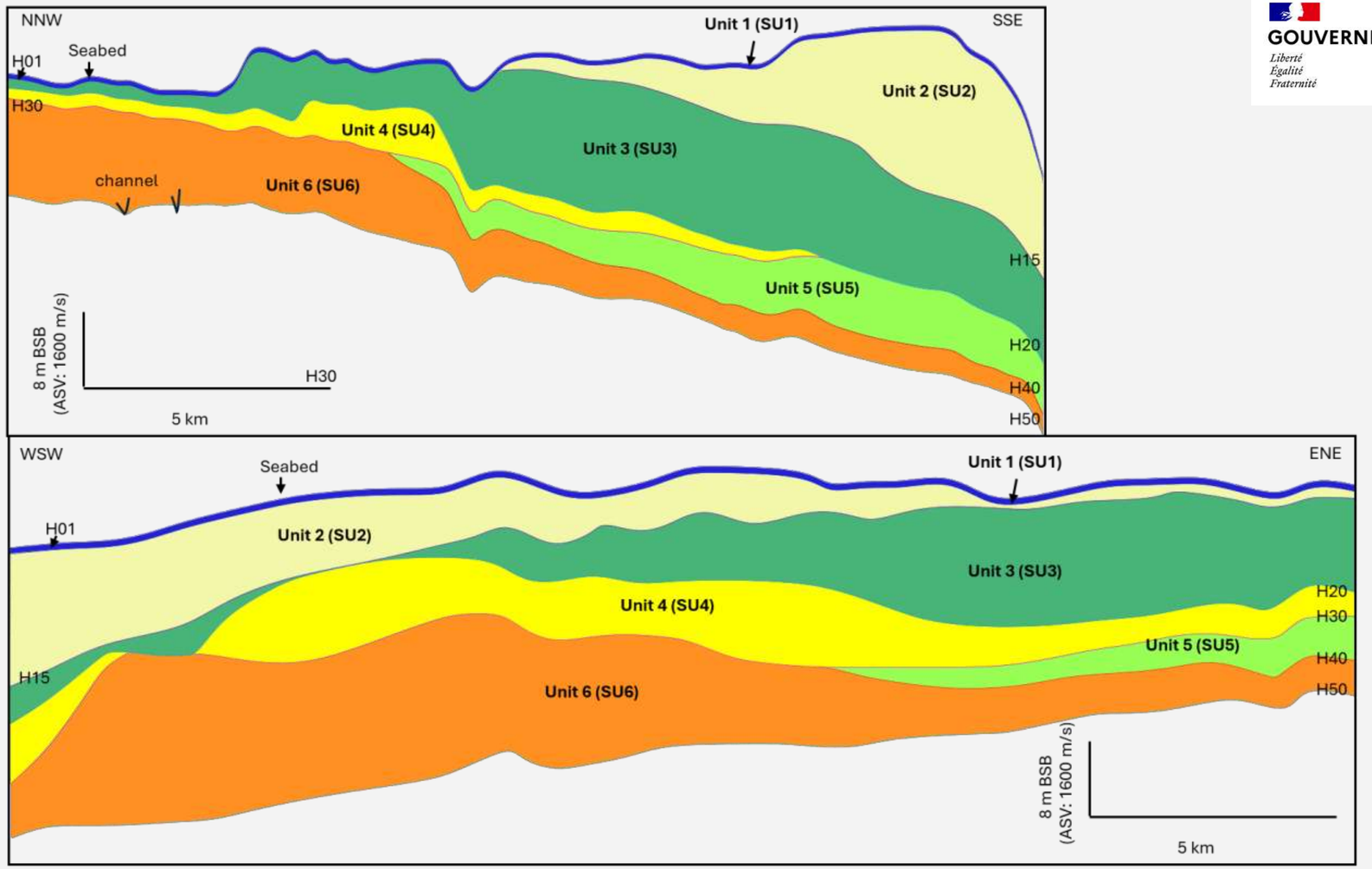
Geological and Geotechnical Integration

Correlation of and boreholes with UHRS and SBP profiles, identifying key seismic horizons and engineering Soil Units.

Soil Unit	Description
SU1	Extremely low to low strength clay
SU2	Dense to very dense sand
SU3	Low to high strength clay
SU4	Dense to very dense sand
SU5	Loose to medium dense sand with clay beds
SU6	Very dense silty sand with occasional clay beds

Ground Model

Six correlated horizons identified.



- Regional continuity established using UHRS and SBP interpretation
- Alternation of clay and sand-dominated units.
- Lateral variability in thickness of sedimentary units.
- Ground model developed for preliminary engineering assessment.

Geohazards

Geohazard / Constraint	Risk Level	Main Observation	Potential Impact for Development
Variable Ground Conditions	Moderate	Alternating clay and sand units with significant thickness variability across the site.	May require different foundation solutions and adaptation of design parameters between turbine locations.
Slope Stability	Moderate	Continental shelf break located in the southeastern sector, with local steep slopes.	Local instability risks may need assessment during detailed design.
Canyons	Moderate	Large erosional features with truncation of seismic reflectors.	Potential sediment transport, erosion and variable foundation conditions.
Channels	High	Incised channels with V-shaped morphology and evidence of reflector truncation.	Significant local variability in soil conditions and potential impact on foundation placement.
Depressions	Moderate	Irregular seabed depressions distributed across the site.	Possible erosional features that may influence foundation and cable routing design.
Migrating Bedforms (Sand Waves)	Moderate	Sand waves mainly located in the southeastern area.	Potential seabed mobility, scour and changes in seabed elevation over time.
Seabed Mounds	Moderate	Localized mounds of uncertain origin identified throughout the site.	May require additional investigation to confirm origin and engineering significance.
Chaotic Seabed Features	Low	Limited areas with irregular seabed morphology.	Local constraint only; limited impact anticipated at regional scale.
Shallow Gas	Low	No evidence identified in available geophysical data.	Low risk based on current information.
Buried Channels	Low	Limited buried channel features identified within deeper units.	May introduce local variability in ground conditions.
Seismogenic Faults	Low	No fault scarps or clear faulting observed in the available datasets.	Low risk identified; however, additional high-resolution seismic surveys may be required during project development.

Key Findings and Risks

Main Findings

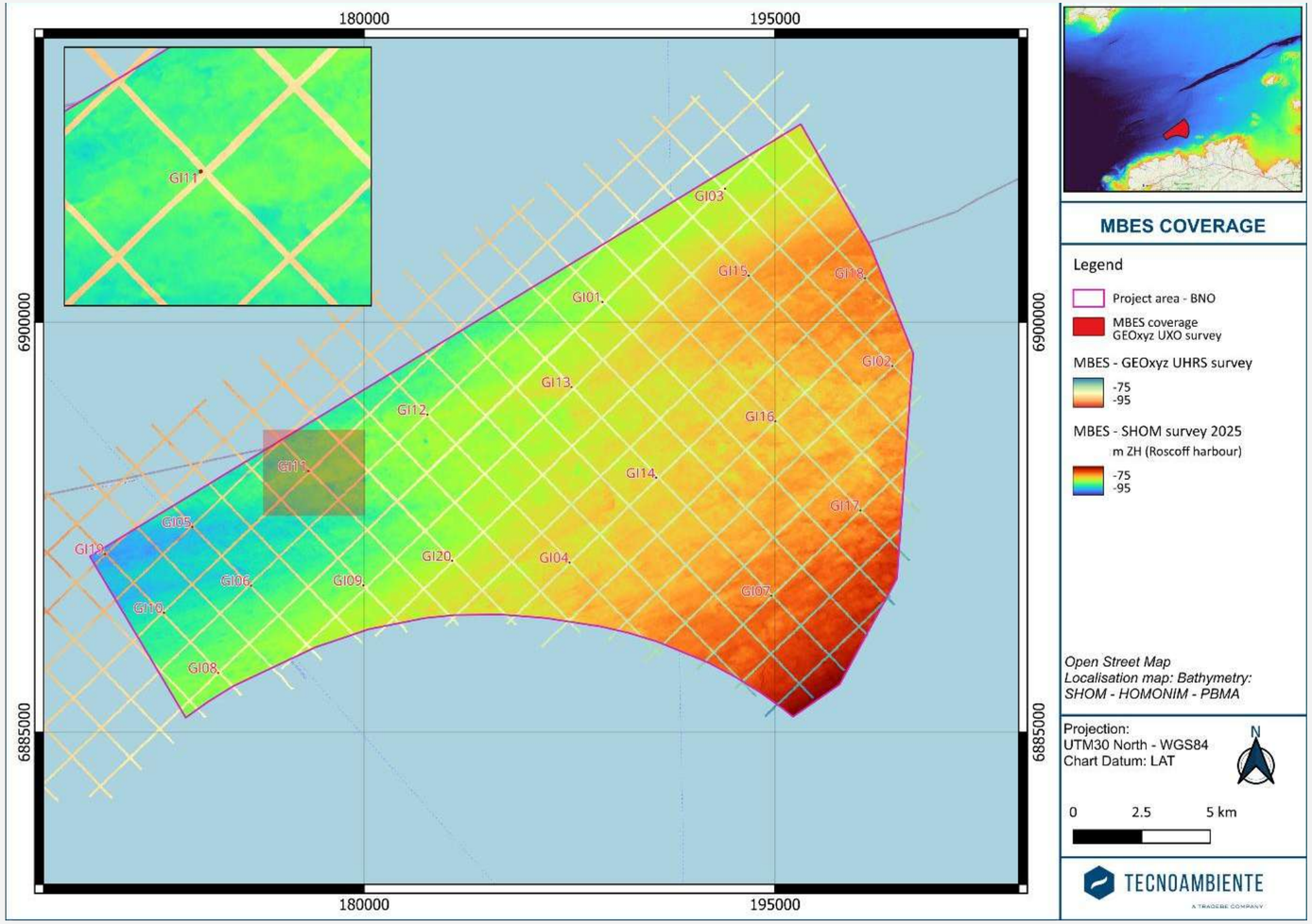
- Well-developed stratigraphic succession,
- Regionally continuous seismic horizons,
- presence of channels and erosional features
- Strong benefits from integrating geophysical and geotechnical datasets.

Main Uncertainties

- Large spacing between seismic lines (~1500 m),
- only six boreholes over a 399 km² area,
- extrapolation required from boreholes
- additional investigations recommended for design.

The integrated interpretation has enabled the development of a regional ground model combining geophysical continuity with geotechnical calibration. Six engineering Soil Units and associated horizons were identified, providing a robust basis for preliminary foundation design and future site development while highlighting areas where additional investigation may be required.

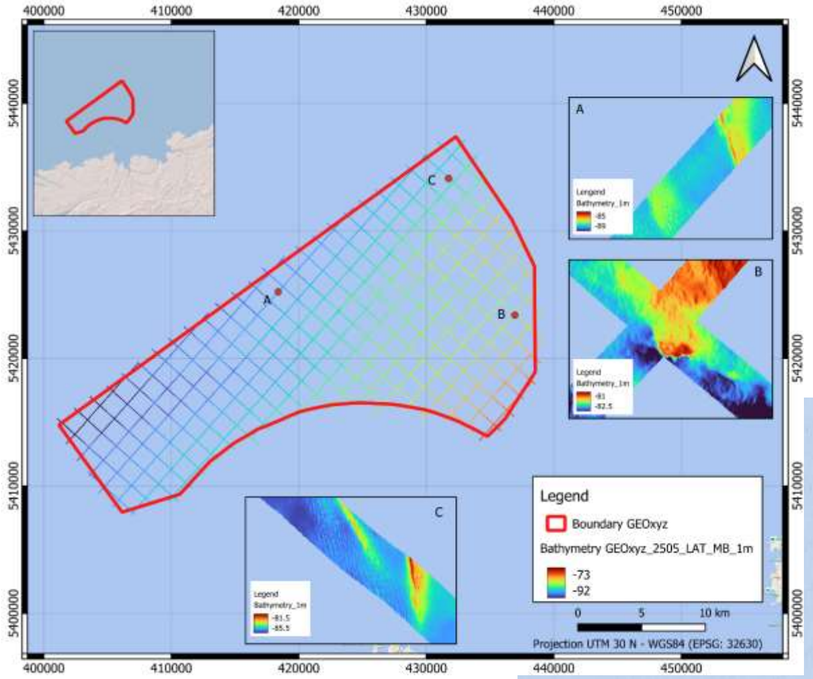
BNO



- Located Offshore Brittany, France, 20 km north-west of Roscoff
- Water depths ranging from 71 to 94 m LAT
- Area: approximately 351 km²
- Shallow offshore plateau dominated by a widespread calcarenite formation overlain by a thin gravel veneer

Available Data

The data sources are organised into two categories: Geophysical and Geotechnical.



Geophysical

- MBES
- SSS
- SBP,
- UHRS
- UXO

Geotechnical

- 13 composite Boreholes
- Rock coring
- Grab samples
- Laboratory testing

Seabed Conditions

Overview of depth, slope, and geological characteristics

Water depth

Between 71 and 94 m.

Seabed slope

Generally <1.5º across the site with a maximum of 15º.

Bedforms

Sand waves, longitudinal bedforms, boulder fields, Depressions and limited sediments fields

Seabed morphology

Relatively flat seabed over most of the site. Local rocky outcrops. Boulder fields. Isolated depressions. Areas of increased seabed roughness associated with exposed calcarenite.

Anthropogenic features

Trawl marks locally observed, Isolated seabed objects detected,

Sediment distribution

Gravelly sediments, Extensive subcropping **calcarenite**

Key findings

Morphology controlled by shallow calcarenite and rocky outcrops, Thin superficial gravel layer over widespread calcarenite

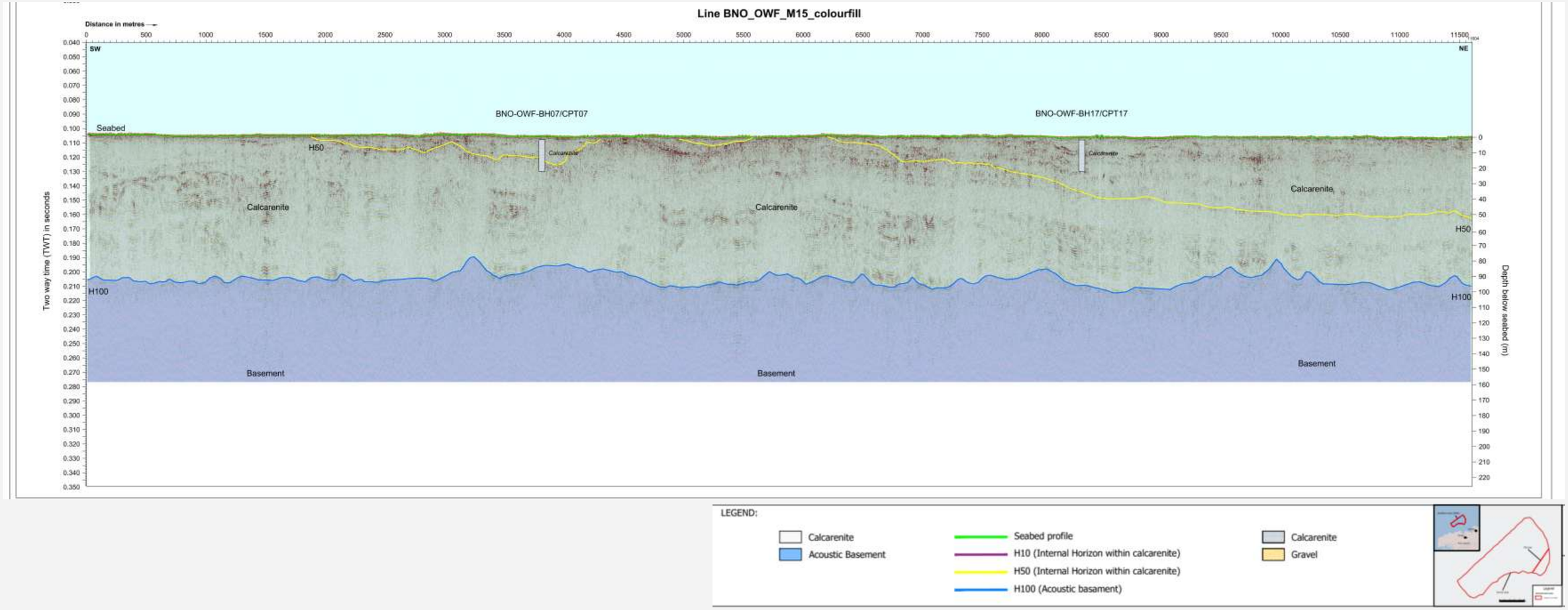
Geological and Geotechnical Integration

Correlation of and boreholes with UHRS and SBP profiles, identifying key seismic horizons and engineering Soil Units.

Soil Unit	Description	Distribution	Engineering Behaviour
SU1 – Gravel	Gravel with sand and shell fragments forming a thin surficial veneer	Widespread but generally thin	Dense granular layer; high frictional resistance
SU2 – Clay	Soft to firm clay deposit	Only identified at **BH01**	Low strength cohesive material; local occurrence
SU3 – Calcarenite	Weak to strong calcareous sandstone (calcarenite) with variable weathering and cementation	Dominant unit across the site	High variability in strength and stiffness; governs foundation and anchor behaviour

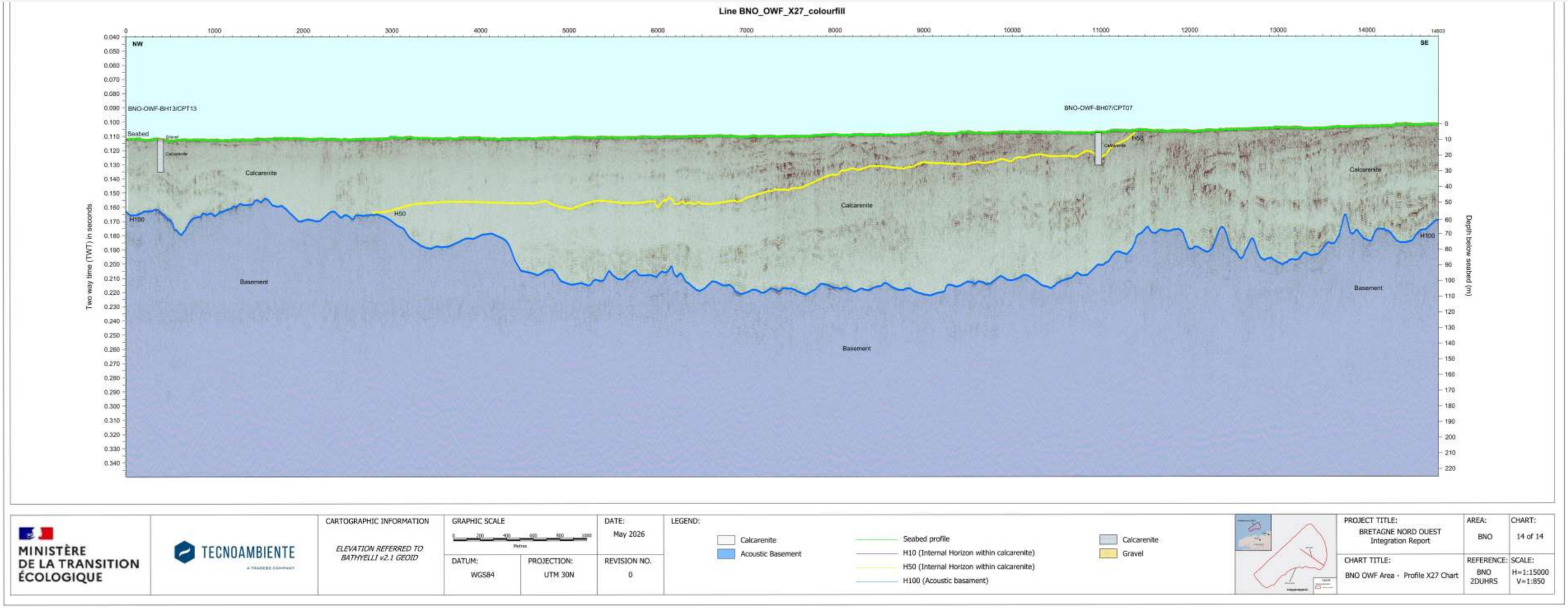
Ground Model

Correlated horizons identified.



Ground Model

Correlated horizons identified.



The BNO ground model is considerably simpler than the Mediterranean sites, being dominated by a single calcarenite formation. The primary engineering challenge is not stratigraphic complexity but the variability of calcarenite strength, weathering and rock mass quality across the site.

Geohazards

Geohazard / Constraint	Risk Level	Observation	Potential Impact
Rock Outcrops / Shallow Calcarenite	High	Calcarenite frequently subcrops at or near seabed.	Anchor installation difficulties, variable penetration depths, foundation interaction with rock.
Boulder Fields	High	Numerous boulder accumulations identified in MBES/SSS data.	Local installation constraints and micrositing requirements.
Variable Calcarenite Strength	High	Significant variability in weathering, cementation and rock quality.	Uncertainty in foundation and anchor performance.
Steep Local Slopes	Moderate	Localized gradients exceeding 15° associated with outcrops and bedforms.	Installation and cable routing constraints.
Sand Waves / Megaripples	Moderate	Localized bedforms present in the central and northeastern sectors.	Potential seabed mobility and local scour considerations.
Depressions	Moderate	Several localized depressions identified.	Local variability in sediment thickness and seabed conditions.
Geological Variability	Moderate	Rapid lateral changes between gravel veneer and calcarenite exposure.	Increased uncertainty between investigation locations.
Faulting	Low	No significant fault systems identified within the development area.	Limited engineering significance.
Shallow Gas	Low	No evidence of shallow gas accumulations observed.	Negligible risk.
Anthropogenic Objects / UXO	Low	Potential UXO contacts identified and managed through dedicated survey and ALARP process.	Local avoidance during detailed design.

Key Findings and Risks

Main Findings

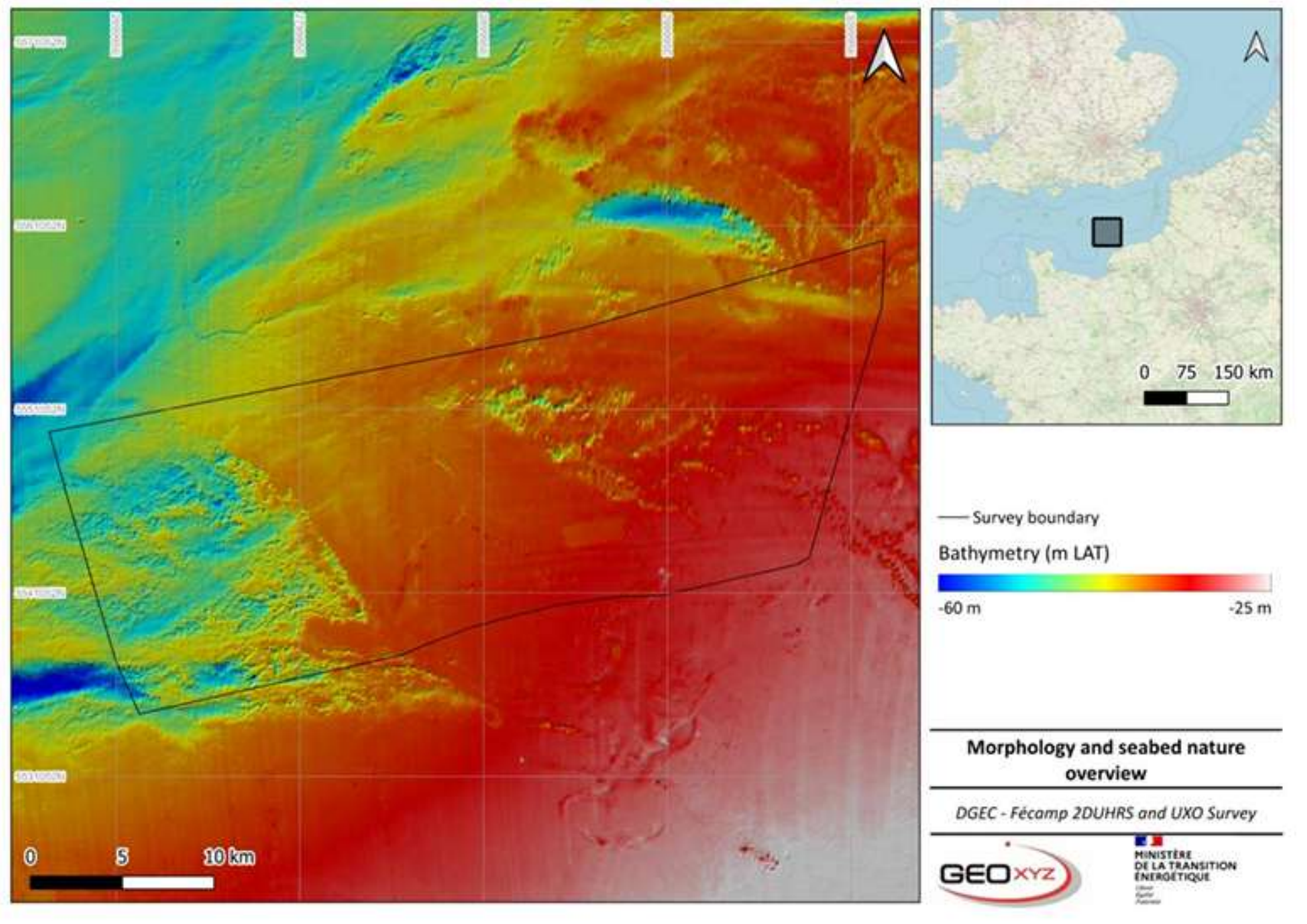
- Integration of **UHRS, SBP, MBES, SSS, UXO and geotechnical datasets** into a single geological and geotechnical ground model.
- BNO is characterized by a **thin superficial gravel layer over a widespread calcarenite formation**, which controls the geotechnical behaviour of the site.
- Bathymetry is generally favourable for offshore wind development
- Ground model and derived geotechnical parameters provide a suitable basis for **preliminary concept design studies**.

Main Uncertainties

- **Wide seismic line spacing (~1500 m)** limits confidence between UHRS lines and requires significant extrapolation across the site
- **Limited geotechnical coverage**
  - 13 boreholes across a 351 km² area
  - Ground conditions between boreholes remain interpolated.
- **Variable calcarenite properties**
  - Degree of weathering
  - Cementation
  - Fracturing
  - Rock strength
- **Poor rock core recovery and discontinuous CPT records** reduce confidence in defining exact unit boundaries and rock quality variations

BNO is a geologically simple but mechanically variable site. The main uncertainty is not stratigraphic complexity but the spatial variability of the calcarenite formation and the relatively sparse geotechnical dataset. Future development phases should focus on refining calcarenite characterization at foundation and anchor locations.

Fecamp Grang Large (FGL)

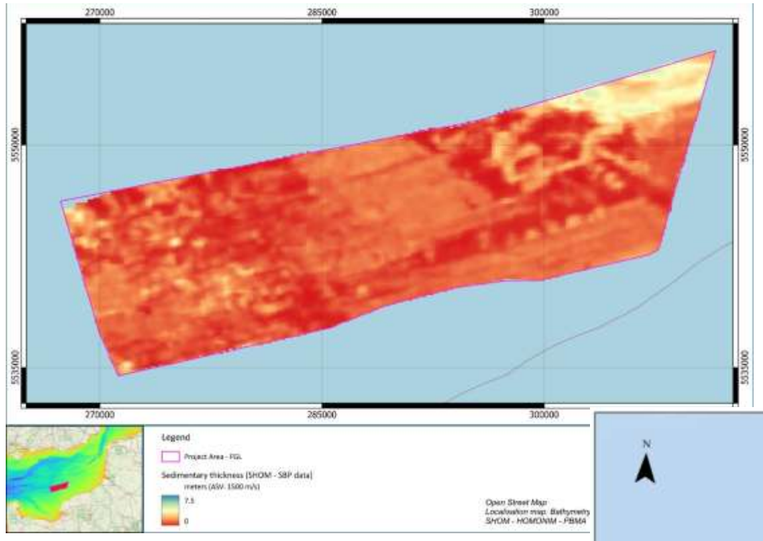


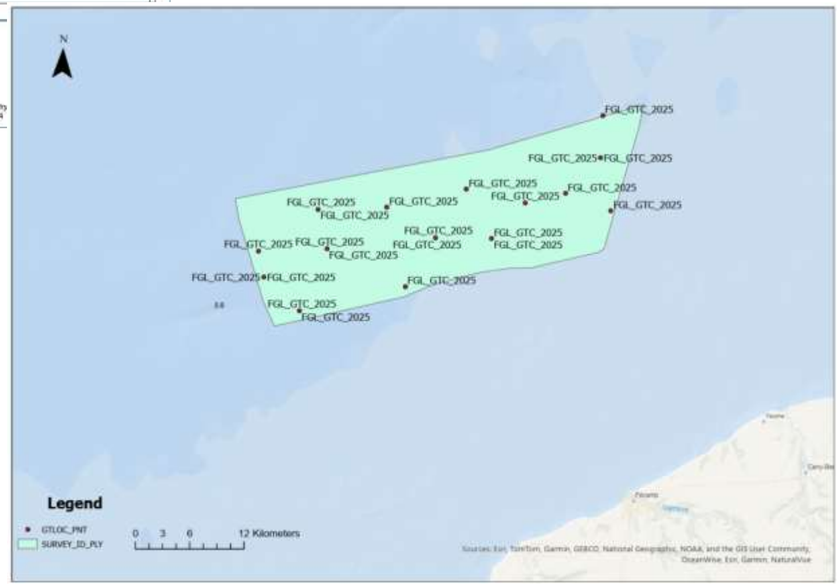
- Located within the **Eastern Channel – North Sea (MEMN) façade**, offshore Normandy at 30km of Fécamp.
- Continental shelf setting approximately 12–50 NM offshore.
- Water depths range from **-29.7 m LAT to -58.5 m LAT**.
- Area: approximately 483 km²
- Located on the western margin of the **Dieppe–Hampshire Basin**.
- Strong tectonic influence from:
  - **Fécamp–Lillebonne Fault System**
  - **Eastern Fault System**

Integration of geological, geophysical and geotechnical datasets is underway.

Available Data

The data sources are organised into two categories: Geophysical and Geotechnical.





Geophysical

- MBES
- SSS
- SBP,
- UHRS
- UXO

Geotechnical

- 23 Boreholes
- 23 CPT,
- Rock coring
- Laboratory testing

Seabed Conditions

Overview of depth, slope, and geological characteristics

Water depth

Between 29 and 59 m.

Seabed slope

Depth increases from east to west

South-East (~30 m)

South-West (~58 m)

Seabed morphology

Sector	Morphological Characteristics
Eastern & Central Areas	Smooth seabed, relatively uniform relief
Eastern Margin	Sub-parallel escarpments
Western Area	Rough seabed with irregular relief
South-West	Structurally controlled morphology associated with major faulting

Anthropogenic features

Feature	Observation
Existing Infrastructure	None identified within survey area
Wrecks	11 wrecks identified within site boundary
Dangerous Wrecks	2 located along planned survey corridors
Non-dangerous Wrecks	1 located along planned survey corridors

Sediment distribution

Material	Distribution
Sand	Widespread superficial veneer
Gravel	Common within surficial deposits
Clayey Silt	Minor component of surficial sediments
Chalk Subcrop	Extensive across central site
Eocene / Cretaceous / Jurassic Units	Locally subcropping close to seabed

Seabed Conditions

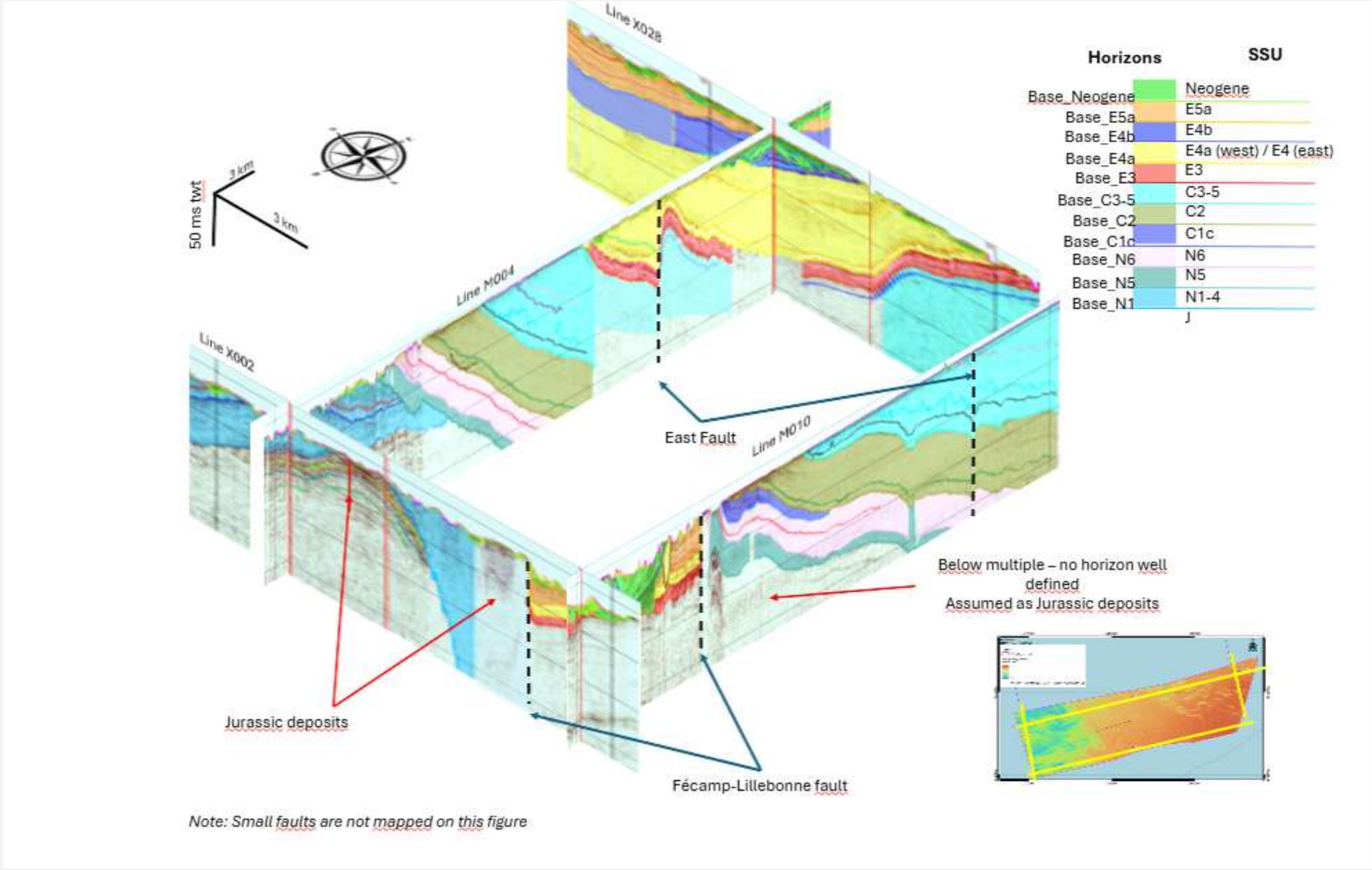
Overview of depth, slope, and geological characteristics

Key Findings

- Water depths suitable for offshore wind development (30–58 m).
- Thin and locally discontinuous Holocene sediment cover.
- Extensive shallow subcrop of older geological formations.
- Strong contrast between smooth eastern seabed and rough western seabed.
- Seabed morphology controlled primarily by geological structure rather than sedimentary processes.
- No evidence of significant active sediment mobility.
- Local constraints associated with wrecks and structurally controlled seabed roughness.

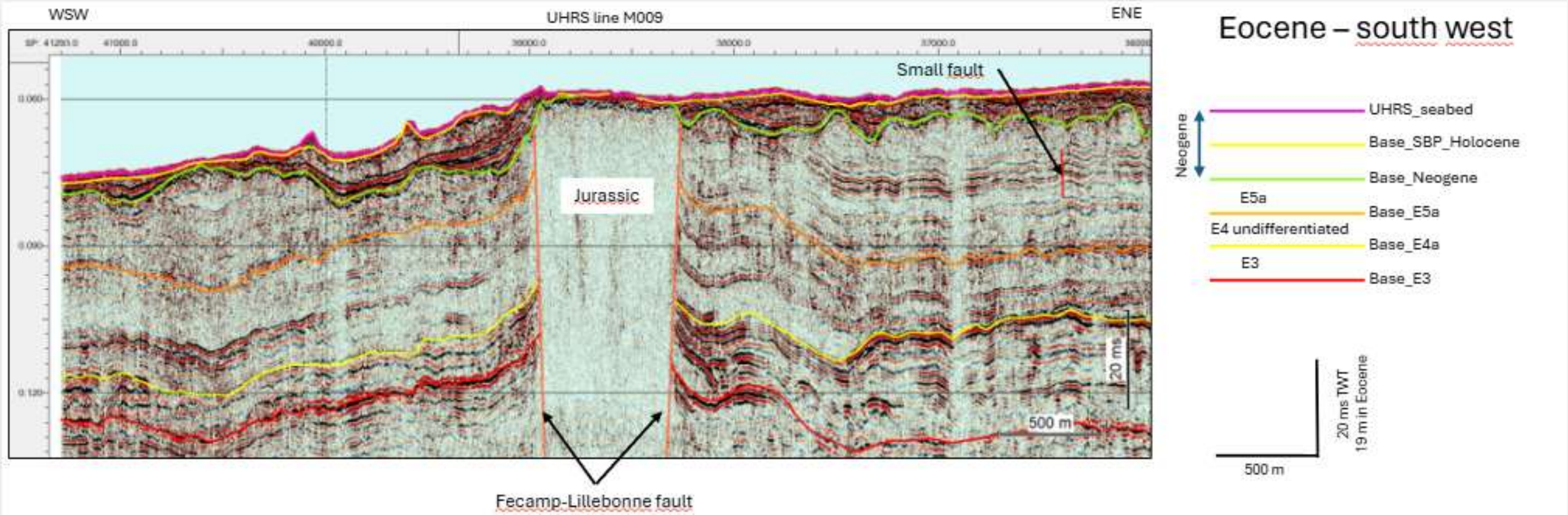
Geological and Geotechnical Integration

Correlation of and boreholes with UHRS and SBP profiles, identifying key seismic horizons and engineering Soil Units.



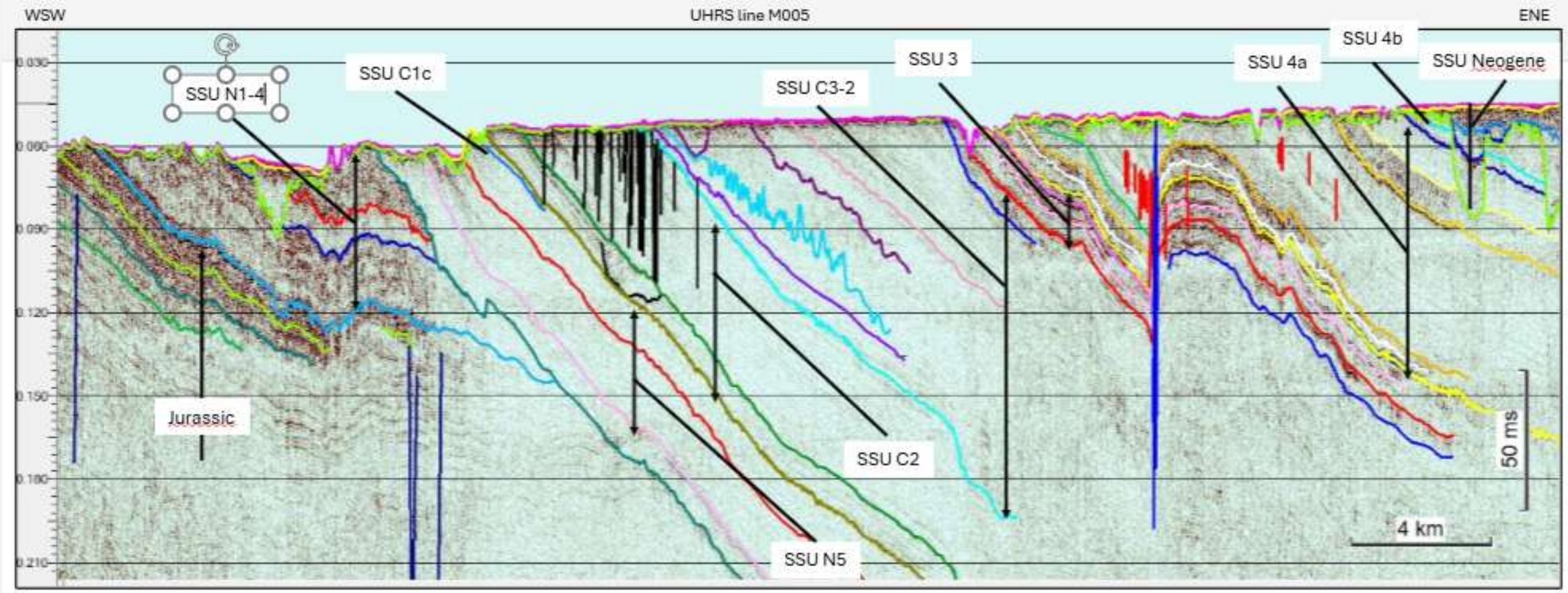
Ground Model

Correlated horizons identified.



Ground Model

Correlated horizons identified.



Geohazards

Geohazard / Constraint	Preliminary Risk	Evidence	Potential Impact
Fault Zones	High	Numerous faults associated with the Fécamp–Lillebonne and Eastern Fault Systems.	Abrupt changes in geology, rockhead variability, fractured ground conditions.
Variable Rockhead Depth	High	Thin Holocene cover with multiple geological units subcropping at seabed.	Variable foundation and anchor behaviour.
Chalk Subcrop / Hard Ground	High	Extensive Upper Cretaceous chalk present close to seabed.	Installation constraints and variable penetration resistance.
Flint Horizons within Chalk	Moderate–High	Expected within Upper Cretaceous chalk formations.	Drilling difficulties and increased wear during installation.
Faulted & Fractured Rock Masses	Moderate	Associated with regional tectonic structures.	Reduced rock mass quality and localized instability.
Buried Channels / Neogene Infill Deposits	Moderate	Localized depocentres with sediment thicknesses up to ~60 m.	Significant changes in geotechnical conditions over short distances.
Steep Seabed Escarpments	Moderate	Observed mainly in eastern and structurally controlled sectors.	Cable routing and installation constraints.
Shallow Gas Anomalies	Moderate	Scattered shallow gas indicators identified in seismic interpretation.	Local drilling and installation risk.
Seabed Roughness / Rock Outcrop	Moderate	Western sector characterized by irregular relief and rocky seabed.	Micrositing and anchor placement constraints.
Mobile Bedforms	Low	No significant active sediment mobility identified.	Limited impact expected.
Mass Transport Deposits / Slope Instability	Low	No evidence identified to date.	Negligible risk.
Wrecks and Anthropogenic Features	Low	Several wrecks identified within the survey area.	Local avoidance during development.

Key Findings and Risks

Main Findings

- No critical showstoppers identified to date.
- Geological complexity is primarily controlled by **tectonic structures and variable rockhead conditions**.
- Ground conditions appear considerably more heterogeneous than other áreas presented

Main Uncertainties

- Fault-controlled geology
- Chalk and flint horizons
- Buried channel-fill deposits
- Variable sediment thickness

Preliminary assessment based on available geophysical interpretation and regional geological information. Geohazard classification may be refined following completion of the integrated geological and geotechnical interpretation.

Geophysical – Geotechnical Ground data Integration and Interpretation.

Integration and interpretation of Geophysical and Geotechnical data for offshore wind development de-risking.

François Lopez Menviel – Tecnoambiente
Alessandro Natale – Tecnoambiente
29 / 06 / 2026

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