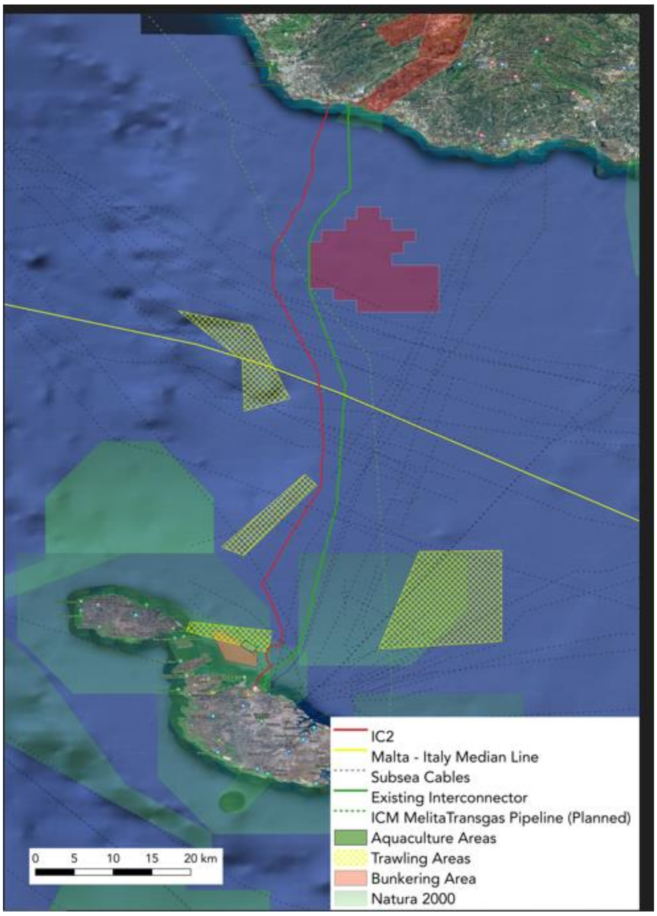
Ref:

Interconnector 2
Environmental Impact Assessment For Malta
Geology, Geomorphology, Hydrogeology, and Soils
Baseline Study and Report



Technical Report

CLIENT REF. No: Ref

SIXTH VERSION

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1.0 Introduction

This Report represents the Geo-Environmental study - Geology, Geomorphology, hydrology and Soils - to fulfil the Terms of Reference issued by ERA, in relation to the Environmental Impact Assessment (EIA) for the proposed construction of a second Electrical Interconnector cable between Malta and Sicily (Figure 1).

The Marine surveys were undertaken by FUGRO and covered the entire submarine cable corridor from Sicily to Malta. Fugro is a Dutch multinational public company headquartered in Leidschendam, Netherlands, that specializes in collecting and analyzing geological data, both on land and at sea.

This EIA report shall focus only on the Maltese part of the study, from the Maghtab Enemalta terminal station on Malta up to the boundary of Maltese Exclusive Economic Zone (EEZ) some 52km along the Interconnector route (Figure 1).

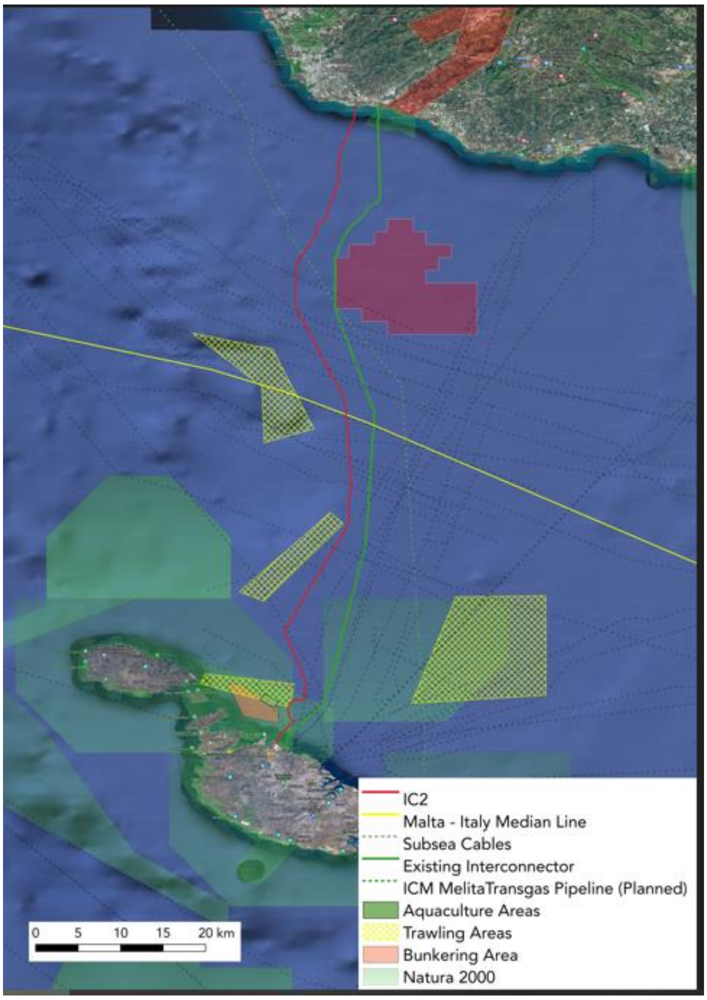

Figure 1: Map showing the Proposed Route for the Electrical interconnector-2 route from Ragusa to Malta

The second HV, 50Hz electrical interconnector project shall consist of an underwater and onshore cable link between the Maghtab Terminal Station and the Ragusa 220kV substation in Sicily. The Interconnector 2 is planned for completion in 2025.

1.1 The project

The second Interconnector shall have a nominal continuous rating capacity of 225MW, and can operate in a bi-directional mode, generally importing electricity from Sicily. The terminal points of the project shall be the 220kV substation at Contrada Cimillà in Ragusa operated by Terna and the Maghtab terminal station operated by Enemalta p.l.c. The cable landing in Malta shall lie between Qalet Marku and Ghallis, while the landing in Sicily shall be situated at Marina di Ragusa.

Trenchless shore approaches shall be adopted in both countries to minimise the environmental and visual impacts on the shore at the proposed landing areas.

1.2 Onshore segment of the IC2 route

The IC2 makes landfall at about 350m north of il-Ghallis Rocks. It crosses the Coast Road and runs along the perimeter road that skirts the entire northern and western margin of the landfill terminating at the Enemalta terminal (Figure 2) .

Figure 2: The IC2 Onshore route shown in red.

To reduce impacts on the environment, the proposed interconnector crosses the coastline and the coast road through a trenchless tunnel.

L-Ghadira s-Safra and L-Iskoll tal-Ghallis are Natura 2000 Sites of Scientific importance located in close proximity to the site (Figure 3). L-Ghadira s-Safra comprises a lesser-known coastal wetland and a rocky shore while L-Iskoll tal-Ghallis supports 'rare biotic assemblages'. They are protected Sites of Scientific

Importance under Government Notice No. 1379 of 2016, in accordance with the Flora, Fauna and Natural Habitats Protection Regulations, 2016 (S.L. 549.44).

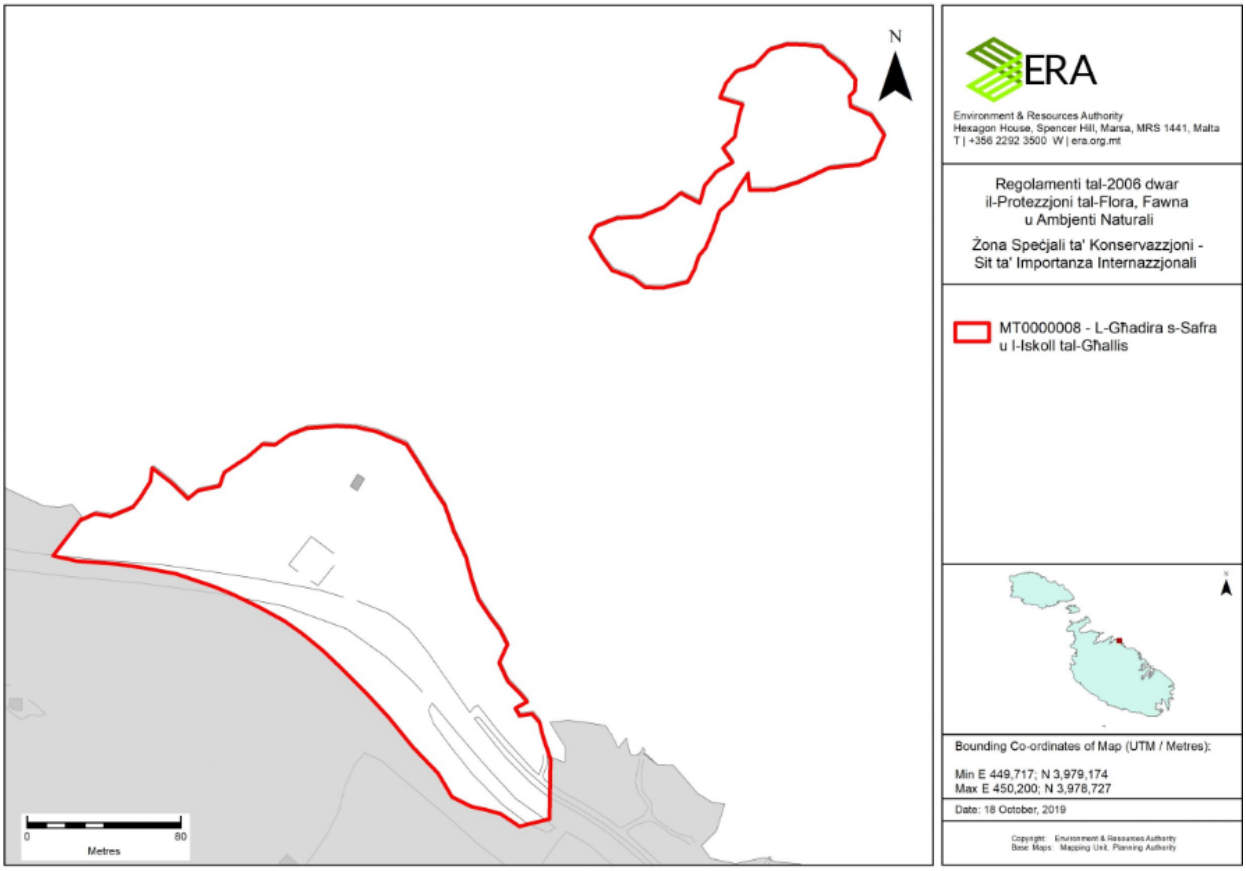

Figure 3: L-Ghadira s-Safra – U l-Iskoll tal-Ghallis Natura 2000 sites of scientific importance

1.3 Offshore segment of the route

For a number of technical and environmental reasons the offshore cable route is not straight but adopts a rather Zig-Zag pattern to avoid sea bed natural features or artificial obstacles such as wrecks, unexploded ordnance (UXO), Oil Exploration Licences and trawling areas.

The maximum water depth along the route on the Maltese EEZ is approximately 160m.

The following list describes the anthropogenic activities along the proposed route.

- **Aquaculture Areas**
- **Trawling Areas**
- **Oil Exploration:** There are no current active licenses on the Continental Shelf along the route of the IC2. The route of the proposed Interconnector skirts the Vega Oil Field on the Italian Continental Shelf.
- **Bunkering areas:** A bunkering area is located some distance from the Ghallis Coastline
- **Subsea cables:** Numerous subsea cables cross the proposed route
- **Natura 2000 sites:** The proposed Cable makes landfall on the il-Kosta Tal-Ghallis Natura 2000 site
- **Existing Interconnector- IC1 offshore** route is seen to run almost parallel but at a distance from the IC2. On land the new route is entirely different from that of the IC1.

- **The EEZ line:** This line marks the northern boundary of the Area of Influence of the current EIA.

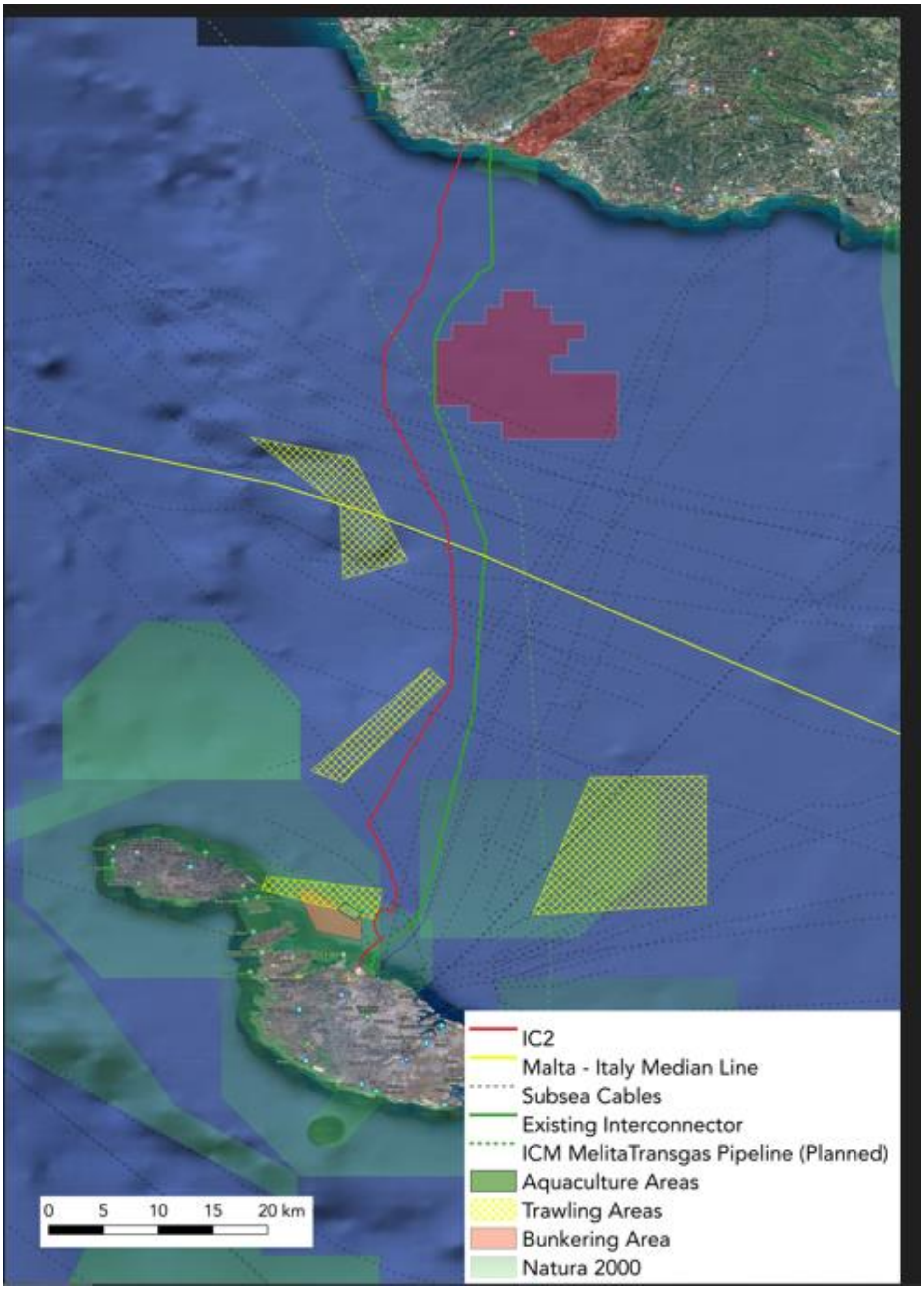

Figure 4: Map showing the offshore route and anthropogenic activities along it

2.0 Terms of reference

The terms of reference issued by ERA were the following:

2.1 A Description of the Site and its Surroundings (i.e. Environmental Baseline)

2.2 Geology, Geomorphology and Hydrogeology

1. The geology and geomorphology of the site and its surroundings, including:

1. *existing geology, stratigraphy, structure, lithology, physiography and geomorphology features;*
2. *palaeontological features;*
3. *hydrogeological features; and*
4. *soil types.*

2. The geo-technical properties and considerations relevant to the site and its area of influence, including:

1. *land stability;*
2. *mechanical, erosional and structural properties of the terrain and land mass;*
3. *any relevant fissures, faults, hollows, or weak points;*
4. *the vulnerability of the site to natural forces such as wave action, erosive elements, landslides and mass movements; and*
5. *any other considerations affecting the implications and risks posed by the proposed development or by any of its ancillary interventions such as site clearance, earth-moving, and excavations.*

3. The quality of the material that will be excavated (including soil, rock/mineral resource, and any existing fill material) and its potential for reuse.

4. Sampling and testing should comply with the relevant standards (unless otherwise agreed, BS standards or other recognised equivalents should be used), and should extend to a sufficient depth below the deepest level of the proposed development (taking into consideration all proposed excavations and underground structures). Wherever the study involves the drilling of core samples, the number, depth and location thereof should also be submitted for ERA approval prior to carrying out of any in situ tests.

5. Any potential adverse effects on features of interest (see points 1 and 2) must be determined. If at risk of being adversely affected, measures to preserve these features should be provided.

2.3 Assessment Of Environmental Impacts And Environmental Risks

All likely significant effects and risks posed by the proposed project on the environment during all relevant phases (including construction/excavation/demolition, operation and decommissioning) should be assessed in detail, taking into account the information emerging from Sections 1, 2 and 3 above. Apart from considering the project on its own merits (i.e. if taken in isolation), the assessment should also take into account the wider surrounding context and should consider the limitations and effects that the surrounding environmental constraints, features and dynamics may exert on the proposed development, thereby identifying any incompatibilities, conflicts, interferences or other relevant implications that may arise if the project is implemented.

In this regard, the assessment should address the following aspects, as applicable for any category of effects or for the overall evaluation of environmental impact, addressing the worst-case scenario wherever relevant:

1. An exhaustive identification and description of the envisaged impacts;

2. The magnitude, severity and significance of the impacts;

3. The geographical extent/range and physical distribution of the impacts, in relation to: site coverage; the features located in the site surroundings; whether the impacts are short-, medium- or long-range; and any transboundary impacts (i.e. impacts affecting other countries);

4. The timing and duration of the impacts (whether the impact is temporary or permanent; short-, medium- or long-term; and reasonable quantification of timeframes);

5. Whether the impacts are reversible or irreversible (including the degree of reversibility in practice and a clear identification of any conditions, assumptions and pre-requisites for reversibility);

6. A comprehensive coverage of direct, indirect, secondary and cumulative impacts, including:

- *interactions (e.g. summative, synergistic, antagonistic, and vicious-cycle effects) between impacts;*
- *interactions or interference with natural or anthropogenic processes and dynamics;*
- *cumulation of the project and its effects with other past, present or reasonably foreseeable developments, activities and land uses and with other relevant baseline situations; and*
- *wider impacts and environmental implications arising from consequent demands, implications and commitments associated with the project (including: displacement of existing uses; new or increased pressures on the environment in the surroundings of the project, including pressures which may be exacerbated by the proposal but of which effects may go beyond the area of influence; and impacts of any additional interventions likely to be triggered or necessitated by situations created, induced or exacerbated by the project);*

7. Whether the impacts are adverse, neutral or beneficial;

8. The sensitivity and resilience of resources, environmental features and receptors vis-à-vis the impacts;

9. Implications and conflicts vis-à-vis environmentally-relevant plans, policies and regulations;

10. The probability of the impacts occurring; and

11. The techniques, methods, calculations and assumptions used in the analyses and predictions, and the confidence level/limits and uncertainties vis-à-vis impact prediction.

The impacts that need to be addressed are detailed further in the sub-sections below.

2.4 Effects on the environmental aspects identified in Section 3

The assessment should thoroughly identify and evaluate the impacts and implications of the project on all the relevant environmental aspects identified in Section 3 above, also taking into account the various considerations outlined in the respective sections.

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2.5 Environmental risk

The assessment should also address, in sufficient detail, any relevant environmental risk (including major-accident scenarios such as contamination, emissions, explosions, blast, flooding, major spillages, etc.) likely to result in environmental damage or deterioration. The range of accident scenarios considered should exhaustively cover, as relevant:

1. one-time risks (e.g. during construction or decommissioning works);

2. recurrent risks during project operation; and

3. risks associated with extreme events (e.g. effect of earthquakes or natural disasters on the project).

The assessment should include, as relevant: a quantification of the risk magnitude and probability; and risk analysis vis-à-vis any hazardous materials stored, handled, or generated on site or transported to/from the site.

2.6 Mitigation Measures

A clear identification and explanation of the measures envisaged to prevent, eliminate, reduce or offset (as relevant) the identified significant adverse effects of the project during all relevant phases including construction, operation and decommissioning.

2.7 Residual Impacts

Any residual impacts [i.e. impacts that cannot be effectively mitigated, or can only be partly mitigated, or which are expected to remain or recur again following exhaustive implementation of mitigation measures] should also be clearly identified.

3.0 Method

3.1 Area of Influence

The off shore Area of Influence for the study shall be the route of the electrical interconnector and shall extend from the Maghtab Enemalta Terminal to the Malta/Italy Exclusive Economic Zone (EEZ) boundary.

3.2 Literature search

Available previous studies in connection with Marine studies along the route of the proposed interconnector Shall be consulted.

3.3 Marine data Review

The baseline study and impact assessment shall be undertaken following the review of the following data set which is to be supplied by the relevant subcontractors:

As per tender document, the PMRS contractor provided the following datasets collected from an investigation of the cable route. This also included accompanying technical reports that must be reviewed for incorporation into the EIA study:

1. Oil/gas exploration areas
2. Wrecks
3. UXOs
4. Underwater faults
5. Bathymetry
6. Morphology maps
7. Geohazards
8. Seabed habitats
9. Sea water sampling
10. Existing infrastructures or obstacles
11. Sediment composition analysis through core penetration testing and grab corers/gravity corers
12. MBES, SBES, SBP, SSS, magnetometer and visual inspections using ROVs
13. Geological stratigraphy
14. Geotechnical properties of upper sedimentary layers
15. Geological and seismological hazard risk assessment
16. ON-bottom strength and sediment instability analysis
17. Landfall feasibility assessment
18. Metocean study covering Qalet Marku to Marina di Ragusa
19. Sediment dispersion modelling at trenchless underwater transitions
20. Nearshore geotechnical surveys through 45m deep boreholes at Qalet Marku

The Front End Engineering Design (FEED) Contractor on the other hand will provide detailed plans, schematic drawings, layouts and technical information about the design of the cable and terminal stations. They will also be able to provide details on construction methodologies, works phasing, on site requirements etc.

3.4 Literature search

Previous studies in connection with Marine studies shall be consulted as well as any literature connected with the laying of the first interconnector

3.5 Geology, geomorphology and Hydrology

This shall be drawn up following review of the marine data provided.

3.6 Geotechnical investigation for rock and seabed sediments properties and reuse - including fissures faults and solution features and land stability.

This shall be drawn up following review of the marine data provided.

3.7 Quality of the material to be excavated

This shall be drawn up following review of the marine and terrestrial data provided.

3.8 Standards and guidance

3.8.1 Strategic Plan for the Environment and Development (SPED)

The SPED replaces the previous Structure Plan (which was published in 1990 and adopted in 1992).

The new Strategic Plan for the Environment and Development (SPED) provides a strategic spatial policy framework for environment and development up to 2020 complementing Government's economic, social and environmental objectives for the same period. The SPED covers the marine waters up to the extent of 25 nautical mile limit of the Fisheries Conservation Zone (adopted by Council Regulation EC No. 1967/2006).

The SPED provides the following guidance in the form of Specific objectives and arising issues listed in (Table 1).:

Theme	Issues
Biodiversity	Despite the legal protection biodiversity continues to be threatened by land development, invasive alien species, overexploitation and climate change
Land	The small size of the Islands and high population density result in competing demands for land. There is a tendency towards inefficient use of land through over provision of development
Soil	arising mainly from increased urbanisation, intensification of agricultural
Mineral resources	resources Extraction practices lead to wastage of resource
Water resources including marine waters	pollution and development that alters the hydromorphology of these waters.
Built heritage and archaeological remains	Demolition, inappropriate design and use of new and restored buildings which undermines street character as well as pilferage of underwater heritage remain a threat especially if these are not afforded legal protection.
Cultural landscape and coastal development,	Malta's cultural landscape is threatened by the extent of built-up area, industrial taller buildings on urban fringes that obstruct views of historic centres, modern agricultural practices, increased vehicular access, litter, poor standards of design and work, and lack of maintenance.

Air quality	Malta's significant air pollutants are particulates and nitrogen dioxide mainly arising from traffic, industry and energy generation and ozone mainly from transboundary sources.
Noise	Heavy traffic is the main source of ambient noise in the Maltese Islands.
Use of Chemicals	Misuse, poor collection, storage and treatment of chemicals may lead to air, water, and sediment and soil pollution. Pesticides and biocidal products are considered to be of particular concern.
Solid waste management	Malta's solid waste management practice is heavily dependent on landfills with low levels of material recovery. Construction and demolition waste makes up a significant proportion of total solid waste generated and the associated impacts are land take up, pollution and nuisance related to transport and depletion of mineral resources.
Climate change	The Maltese Islands are vulnerable to the predicted impacts of climate change. A decrease in annual precipitation that may lead to episodes of drought, more intensive storm events leading to flooding and predicted changes in global sea levels are likely to affect ecological processes and consequently the socioeconomic activities and infrastructure which depend on them. Energy including transport is the main source of Greenhouse Gas Emissions. Targets for non ETS sector are challenging.

Table 1: SEA Objectives and respective Issues (Strategic Plan for Environment and Development, Statement of adoption July 2015)

3.9 Details of WP1-Preliminary Marine Route Survey (PMRS)

In detail, Work Package 1 was divided into three phases as per below:

1. Nearshore Italy PMRS:
   - Geophysical survey (MBES, SSS, Magnetometer, SBP).
   - ROV Environmental survey.
   - Geotechnical Survey: Grab samples, Gravity Cores and CPT.
   - Environmental Survey: Water, Sediment and plankton sampling.
2. Nearshore Malta PMRS:
   - Geophysical survey (MBES, SSS, Magnetometer, SBP).
   - ROV Environmental survey.
   - Geotechnical Survey: Grab samples, Gravity Cores and CPT.
   - Environmental Survey: Water, Sediment and plankton sampling.
3. Offshore Cable Corridor PMRS:
   - Geophysical survey (MBES, SSS, Magnetometer, SBP).
   - ROV Visual Inspection.
   - Geotechnical Survey: Grab samples, Gravity Cores and CPT.
   - Environmental Survey: Water, Sediment and plankton sampling

3.9.1 The survey Tools

The Marine Geophysical Survey was undertaken using the following tools:

- Multibeam echosounder (MBES)
- Side Scan Sonar (SSS)
- Magnetometer
- Sub-Bottom profiler(SBP)
- ROV   Remotely Operated Vehicle

3.9.2 Operations - The Survey Vessels

Fugro used the Italian-flagged research vessel MV Urbano Monti for the Offshore survey, the Maltese-flagged research vessel MB Wilfred for the Nearshore Malta survey and the Italian-flagged research vessel MB Beam for the Sicily Nearshore survey. These vessels were utilized in similar surveys and proven to be a stable platform for carrying out the investigation efficiently and safely.

MV Urbano Monti is a vessel designed for marine offshore surveys. The mobilization port of MV Urbano Monti was Catania Harbor, Italy.

Figure 5: Malta-Italy Offshore Survey Vessel MV Urbano Monti

Figure 6: Nearshore Malta Geophysical Survey Vessel MB Wilfred

MB Wilfred is a vessel designed for marine offshore survey and was mobilised in Valletta, Malta.

For the shallow water areas (from 0 to 8 m depth), the Nearshore Malta bathymetric survey was carried out by the Sahara Zodiac (Figure 7).

Figure 7: Surf Zone Malta Geophysical Survey – Sahara Zodiac

3.9.3 *Near-shore Malta Area of survey*

The nearshore Malta PMRS data acquisition extends from the coastline to 1 Nautical Mile offshore and consists of 258 line kilometers of survey as detailed in Table 2. A map showing the area covered by the marine geophysical survey is shown Figure 8:

Table 2: Nearshore Malta Geophysical survey Line Plan

Description	No. Lines	Line space	Tot km
MBES & SSS	No. 40 Main lines	40m in water depth from 5m to 10m 60m in water depth greater then 10m	Approx. 45.526
SBP & MAG	No. 191 Main Lines No. 9 SBP cross lines	10 m line spacing for the main lines 200m line spacing for the cross lines	Approx. 207.000
MBES & Backscatter (from 0 to 8 m depth)			Approx. 5.760
		TOTAL	**258.28 incl. infill**

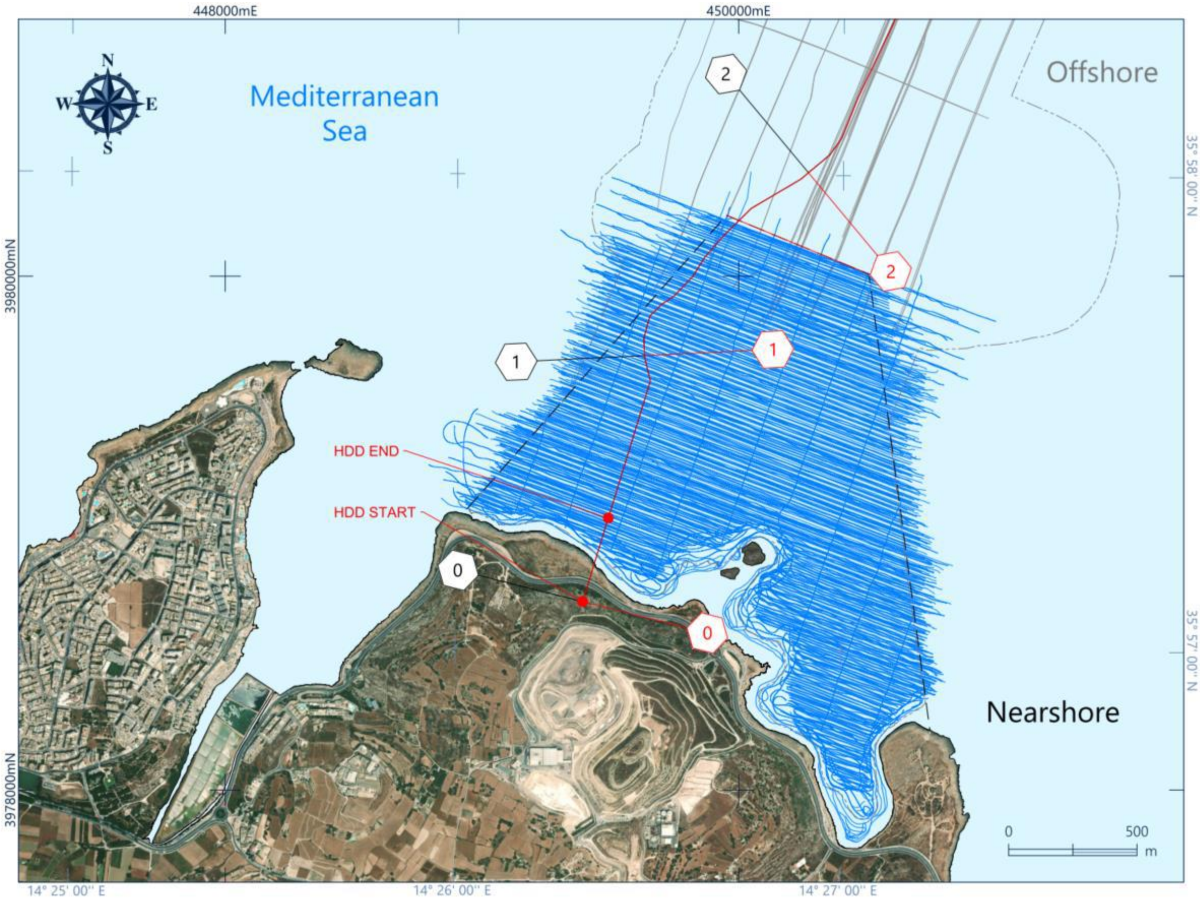


Figure 8: Map showing the detail of the Near shore Malta Survey Lines

3.9.4 Offshore Malta-Italy PMRS

A bathymetric and geophysical survey was carried out in the offshore portion of the deeper route, 600 m wide (Figure 9). As seen in this map the survey corridor is divided into sectors. The relevant part of the study runs from the coastline to the Malta EEZ; that is sector No 1 to sector No 6.

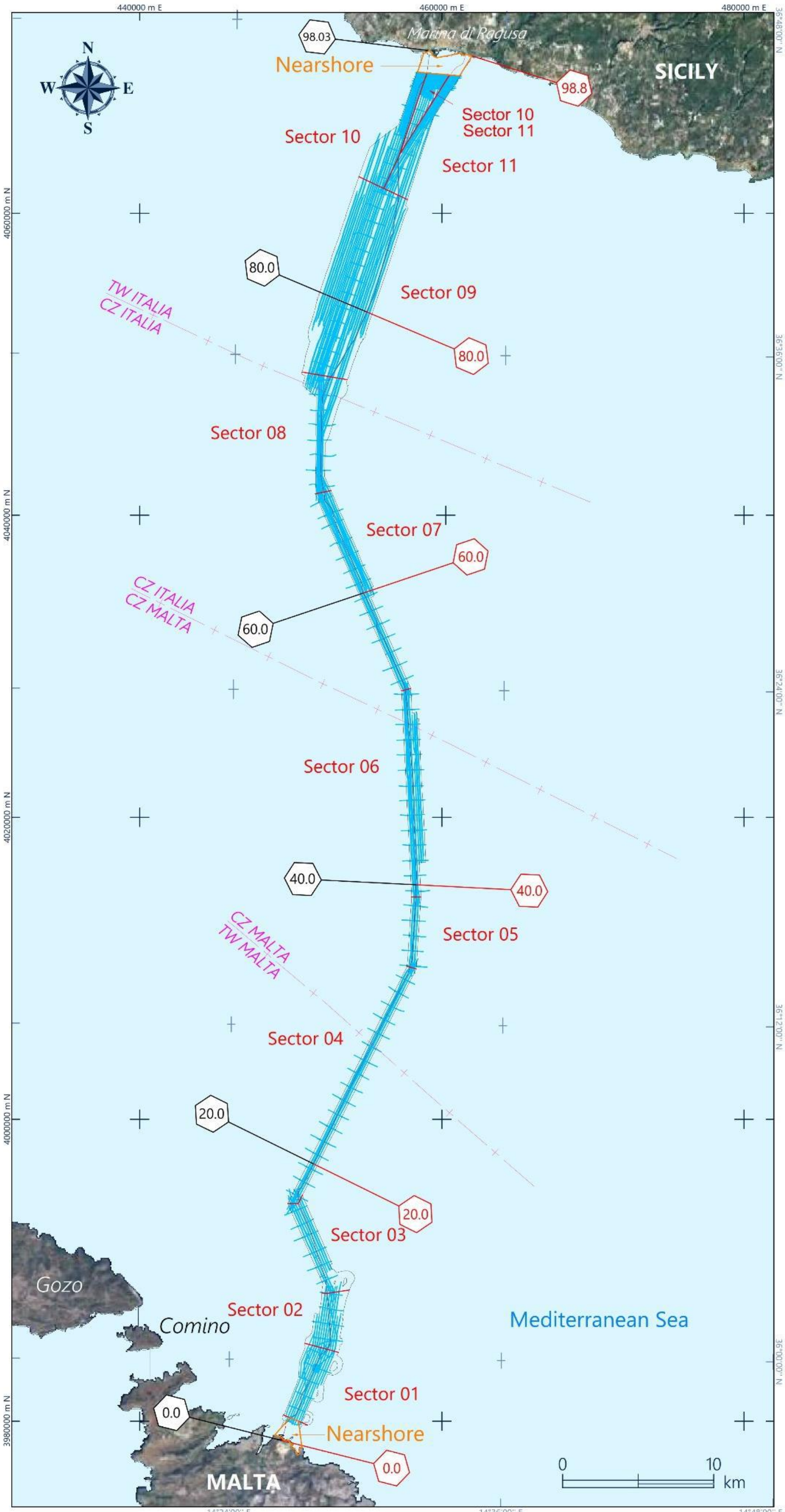


Figure 9: Map showing the 600m corridor offshore Malta (and Italy) covered by the study. The relevant part of the route for this study runs from Nearshore to Sector No 6 at the Malta/ Italy EEZ boundary

A summary of the transect line plan is described below:

- No. 1 x Centre line along the offshore route collecting data from MBES, SSS, SBP and MAG
- No. 2 wing lines (150m from the centre) along the offshore route, collecting data MBES, SSS, SBP and MAG
- 4x lines (10m spaced to cover a central corridor 40m wide) along the offshore route collecting data from Magnetometer. Therefore, a total of 7 longitudinal lines were collected with the Magnetometer.

Following data analysis, any data gaps within the survey corridor were infilled accordingly to achieve full coverage.

- Cross lines were carried out at 1000m spacing over the 600m corridor collecting data from MBES, SSS, SBP and MAG.

During the survey campaign, following the preliminary results, the Client required extra work on sectors 1, 2, 3, 6, 7 and 9. The extra work was performed in order to investigate areas with particular features:

- Sector 1 and 2: presence of a steep scarp.
- Sector 3, 6 and 7: presence of main targets along the proposed route.
- Sector 9: presence of a wide outcrop area.

The data acquisition lines along the IC2 offshore route is summarized in Table 3 below. This amounted to 1,238 line kilometers:

Table 3: Malta Italy Offshore survey corridor line plan

Description	No. Lines	Line space	Tot km
MBES, SSS, SBP & MAG	3 Main Lines (103 km long and 100 Cross Lines (600 m long))	Main lines:150 m spaced + infill Cross lines: 1000 m spaced	Approx. 439.682
MAG	4 Main lines	10 m spaced in a 40 m corridor, centred on the proposed route	Approx. 379.823
MBES, SSS, SBP & MAG	Extra work in S01; S02; S03; S06; S07 and S09		Approx. 418.657
		TOTAL	**1238.162 incl. infill**

3.9.5 Sediment and Seawater sampling protocols

Sediment sampling was performed following relevant guiding standards of the ISO 5667 series Water quality – Sampling, specifically Part 1: Guidance on the design of sampling programmes and sampling techniques; Part 3: Guidance on the preservation and handling of water samples; and Part 19: Guidance on sampling of marine sediments.

The handling and preservation of the samples was carried out in accordance with ISO 5667-15:2009: Water quality – Sampling – Part 15: Guidance on the preservation and handling of sludge and sediment samples.

3.9.6 Nearshore Malta seabed characterisation survey: Sediment and Water Sampling

The seabed characterisation survey consisted of a sediment (Grab samples) and water sampling campaign.
Prior to the starting of operations at sea a proposed sampling plan was shared with the Client and submitted to competent Authorities.

Upon sediment sample retrieval on deck, superficial gravity cores and grab samples were analysed, and classical on-board testing were performed, based on the below requirements.

Table 4: Nearshore Malta seabed characterisation survey – Sediment sampling requirement

Item	Description
Grab Samples	▪ To be stored within 70% ethanol preservative in labelled 10-litre buckets. ▪ The infauna present within the sediment shall be subsequentl filtered through a 0.5 mm sieve to isolate macrofauna, pursuant to computing the bentix and ambi sediment quality indices

Moreover, water column samples were collected by means of Niskin bottles and plankton net for each location.
Water samples for chemical characterisation, phytoplankton, zooplankton analysis were carried out by means of Niskin bottles and plankton nets.

Table 5: Nearshore Malta seabed characterisation Survey – Water sampling requirements

Item	Description
Niskin Bottles	- 0.5m from surface - 0.5m from seabed and - An intermediate water depth
Plankton net	Horizontal plankton tows to be conducted with the following mesh sizes: - 25 microns for phytoplankton sampling purposes - 200 microns for zooplankton sampling purposes
CTD	Water column samples will be collected, and the following parameters will be assessed by means of CTD readings: - Temperature - Salinity - Dissolved oxygen - pH - turbidity - Biological Oxygen Demand - Chemical Oxygen Demand

3.9.7 Offshore seabed characterisation survey: Sediment and Water Sampling

The seabed characterisation survey consisted of a sediment (Grab samples, Gravity cores and CPT) and water sampling campaign. Prior to the starting of operations at sea a proposed sampling plan was shared with InterConnect Malta. Upon sediment sample retrieval on deck, superficial gravity cores and grab samples were analysed, and classical on-board testing were performed, based on the below requirements.

Table 6: Offshore Malta-Italy seabed characterisation survey – Sediment sampling requirements

Item	Description
Gravity core samples	▪ In-situ visual soil description (including colour definition using Munsell Colour Scale) ▪ In-situ HCL (20%) reaction ▪ In-situ Pocket Penetrometer ▪ All collected gravity cores shall be properly labelled every m, sealed with wax and with a cap on the top and on the bottom
Grab Samples	▪ To be stored within 70% ethanol preservative in labelled 10-litre buckets. ▪ The infauna present within the sediment shall be subsequently filtered through a 0.5 mm sieve to isolate macrofauna, pursuant to computing the bentix and ambi sediment quality indices

The methodology of the Gravity core's acquisition is as follows:

- 3 m barrel was used to collect the samples since they were enough following the interpretation of the geophysical survey.

- Where no penetration was expected considering the preliminary interpretation, only one attempt was performed, and then a grab sample was taken instead.

- If there was a recovery of about 50%, a second attempt was performed, and then considered the best of the two coring.

Moreover, water column samples were collected by means of Niskin bottles and plankton nets for each location. Water samples for chemical characterisation, phytoplankton, zooplankton analysis were carried out by means of Niskin bottles and plankton nets.

Table 7: Offshore Malta-Italy seabed characterisation Survey – Water sampling requirements

Item	Description
Niskin Bottles and	- 0.5m from surface - 0.5m from seabed and - An intermediate water depth
Plankton net	Horizontal plankton tows to be conducted with the following mesh sizes: - 25 microns for phytoplankton sampling purposes - 200 microns for zooplankton sampling purposes
CTD	Water column samples will be collected, and the following parameters will be assessed by means of CTD readings: - Temperature - Salinity - Dissolved oxygen - pH - turbidity - Biological Oxygen Demand - Chemical Oxygen Demand

3.9.8 Sediment sampling points

102 shallow geotechnical locations were sampled by Fugro Italia within the offshore survey area (S01-S11) as part of the PMRS. The following geotechnical data were acquired:

- 20 Seabed cone penetration tests (CPTs);
- 50 Seabed gravity core samples;
- 23 Seabed grab samples.

CPT logs, grab sample descriptions, full gravity core sample descriptions and lab testing results were provided by Fugro Italia for input to this study. These data were reviewed and unitised as part of the cable route soil zonation. Geotechnical data were also useful in identifying several geological hazards along the cable route.

Geotechnical locations up to the Malta /Italy EEZ boundary are displayed in Figure 10**Error! Reference source not found.** . Geotechnical data were not acquired in the nearshore survey areas as part of the PMRS.

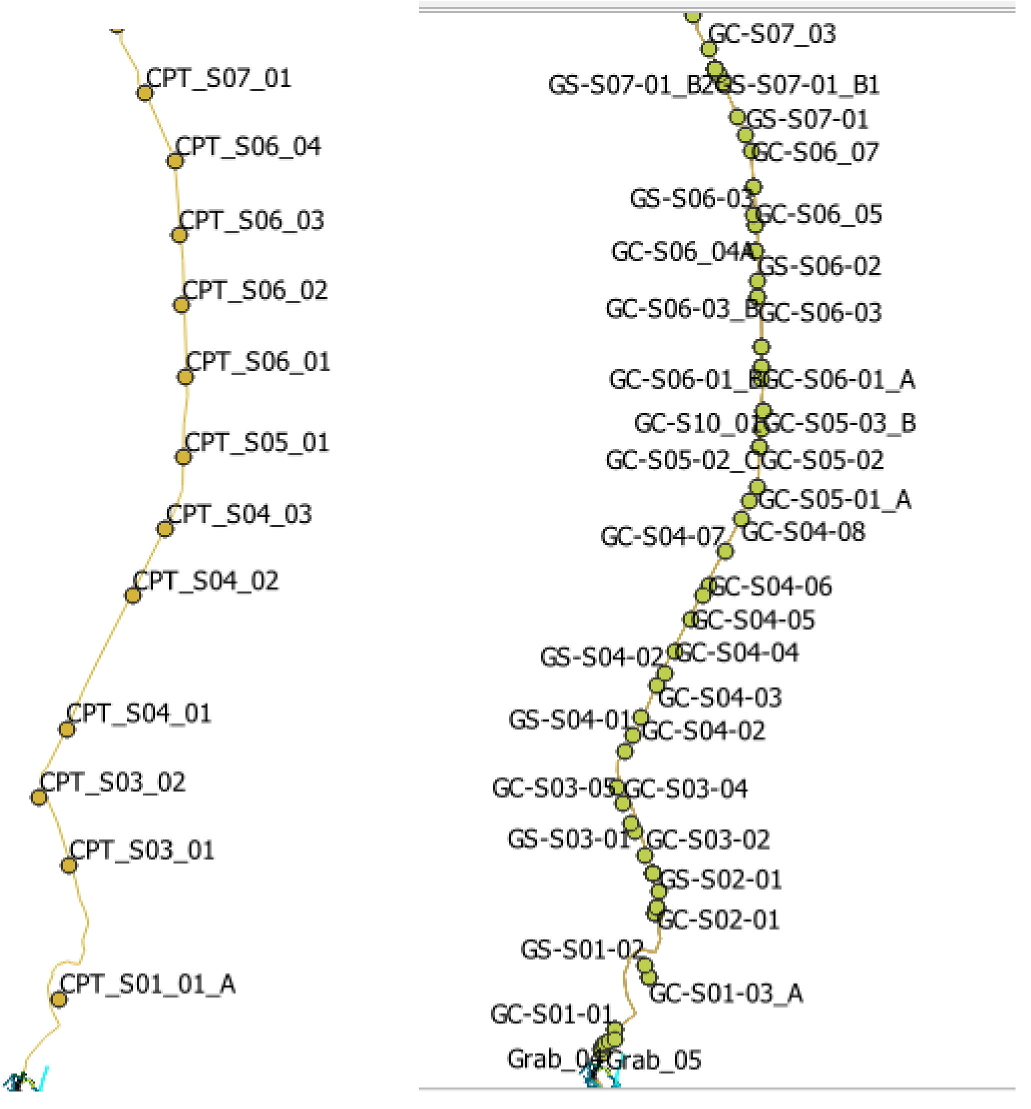


Figure 10: Location of the sediment Sampling Points. CPT: Cone penetration test; GS: Grab sample; GC: gravity core sample

Geotechnical boreholes, onshore and nearshore, have been acquired as part of work package 3 (Section 1.1.1).

3.10 Output

The Geophysical survey results and subsurface investigation shall be presented in the form of:

- Nearshore and offshore seabed geological composition and subsurface geology ;
- Geomorphology and Seabed profiles ;
- Geological and geotechnical Report based on shore, nearshore and offshore investigation;
- Waste stone/soil material quality and characterisation;

4.0 *Project Description and Scope of Works*

4.1 The Project

Interconnect Malta (ICM) is the Malta Government body responsible to implement the second Malta – Sicily electrical interconnector as well as the Melita TransGas pipeline. Both of these developments will be installed between Malta and Sicily.

The second electrical Interconnector project consists of an underwater and onshore cable link between the Maghtab Terminal Station and the Ragusa 220kV substation in Sicily. Similar to the first electrical Interconnector, it will have a nominal continuous rating capacity of 225MW, and can operate in a bi-directional mode, generally importing electricity from Sicily.

The cable will be laid in public roads in Sicily and will avoid private properties as much as possible. The terminal points of the project will be the 220kV substation at Contrada Cimillà in Ragusa operated by Terna and the Maghtab terminal station at Maghtab operated by Enemalta p.l.c.

The cable landing point in Malta will be at l-Ghallis (Bahar ic-Caghaq) while the landing point in Sicily will be sited at Marina di Ragusa with two possible landing points still to be studied.

Trenchless shore approaches will be adopted in both countries to minimize the environmental and visual impacts on the shore at the proposed landing areas.

4.2 Scope of Works

Malta – Italy Interconnector 2 Project consists of a new approximately 118 km long, 225 MW 50Hz electrical cable interconnection through a submarine cable between Malta (Magħtab) and Sicily (Ragusa) to be laid in parallel but at a safe distance to the existing HVAC cable link (Malta – Italy Interconnector 1).

The terminal points of the project will be the 220kV substation at Contrada Cimillà in Ragusa (Sicily) operated by Terna Rete Italia SpA, and the Magħtab terminal station operated by Enemalta p.l.c.

Figure 11: Proposed cable route

A Preliminary Marine Route Survey (PMRS) and Post Survey Assessment Studies (PSA) between Malta and Marina di Ragusa has been undertaken in order to investigate the proposed offshore corridor as well as to identify the most suitable route for the laying of the cable.

In detail, the following services were carried out:

- Desktop Study to confirm the viability of the 600 m proposed cable route survey corridor.
- Preliminary Marine Route Survey (PMRS) with Geophysical, Light Geotechnical, Environmental data acquisition and ROV observations along the proposed cable route. Tot. 103 km long and 600 m wide cable route to determine an optimal 200 m corridor.
- Post Survey Assessment (PSA) including data analysis as well as additional studies to establish a 200 m wide final cable route corridor.
- Investigation of sediment composition, geological stratigraphy, and geotechnical properties of the upper sediment layers.
- Seabed ecological and biodiversity investigation (i.e. marine habitat, water and sediment quality, phytoplankton, zooplankton, benthos, algae, aquatic angiosperm etc.)
- Material characterisation of sediment with superficial grab/box corer, gravity corer
- Study of sediment by means of core penetration testing
- Water and environmental sampling, testing, and reporting.

Operational activities were divided into different “Package”, defined as Work Package (WP), based on the activities that were carried out:

Work Package 1: Execution of the Preliminary Marine Route Survey (PMRS) on the identified IC2 offshore route corridor.

Work Package 2: Execution of the Post Survey Assessments (PSA);

Work Package 3: Nearshore Boreholes:

5.0 Results: Geomorphology of the Seabed

A detailed bathymetric map is here presented, and is discussed in terms of features interpretable as former subaerial landforms and inundated by sea level rise following the Last Glacial Maximum (LGM) lowstand at approximately –130 m. Datasets combine multibeam surveys, Light Detection And Ranging (LiDAR)-derived digital terrain models (DTMs), Chirp sub-bottom profiler records and bottom samples acquired between 2009 and 2012.

The main features identified are (Figure 12):

- former river incisions,
- alluvial plains,
- karst landscapes (sinkholes, limestone plateaus),
- slide deposits and palaeoshorelines.

This study provides a detailed topographical reconstruction of the palaeolandscape of this key region that is relevant to any future geomorphological exploration of the Maltese offshore area.

Along the entire archipelago, the shelf is bounded by a break of slope with a bathymetric depth ranging from 50 to 95 m, and with its base at 120–130 m. From Gozo to Salina Bay (Malta), it is straight, continuous, orientated NW–SE and has a maximum slope gradient of 35°.

The occurrence of the base of the continental escarpment at a depth of 120–130 m substantiates that this feature potentially represents the shoreline of the Maltese archipelago during the LGM, when the parts of the continental shelf now located at a depth of ,130 m were emerged and affected by subaerial processes (Lambeck *et al.* 2011; Micallef *et al.* 2013).

On the continental shelf, we observe a wide variety of terrestrial and marine geomorphological features of different origin that were emergent during the LGM: karst features (sinkholes and karst pavement), features related to slope instability (block slides), fluvial features (former river incision and alluvial plains) and coastal features (palaeo-shorelines and their deposits). The area downslope of the shelf break is defined by a more uniform, smooth and gently sloping morphology, which is mainly a result of fine marine deposits at depths which were never exposed to the subaerial agents of erosion.

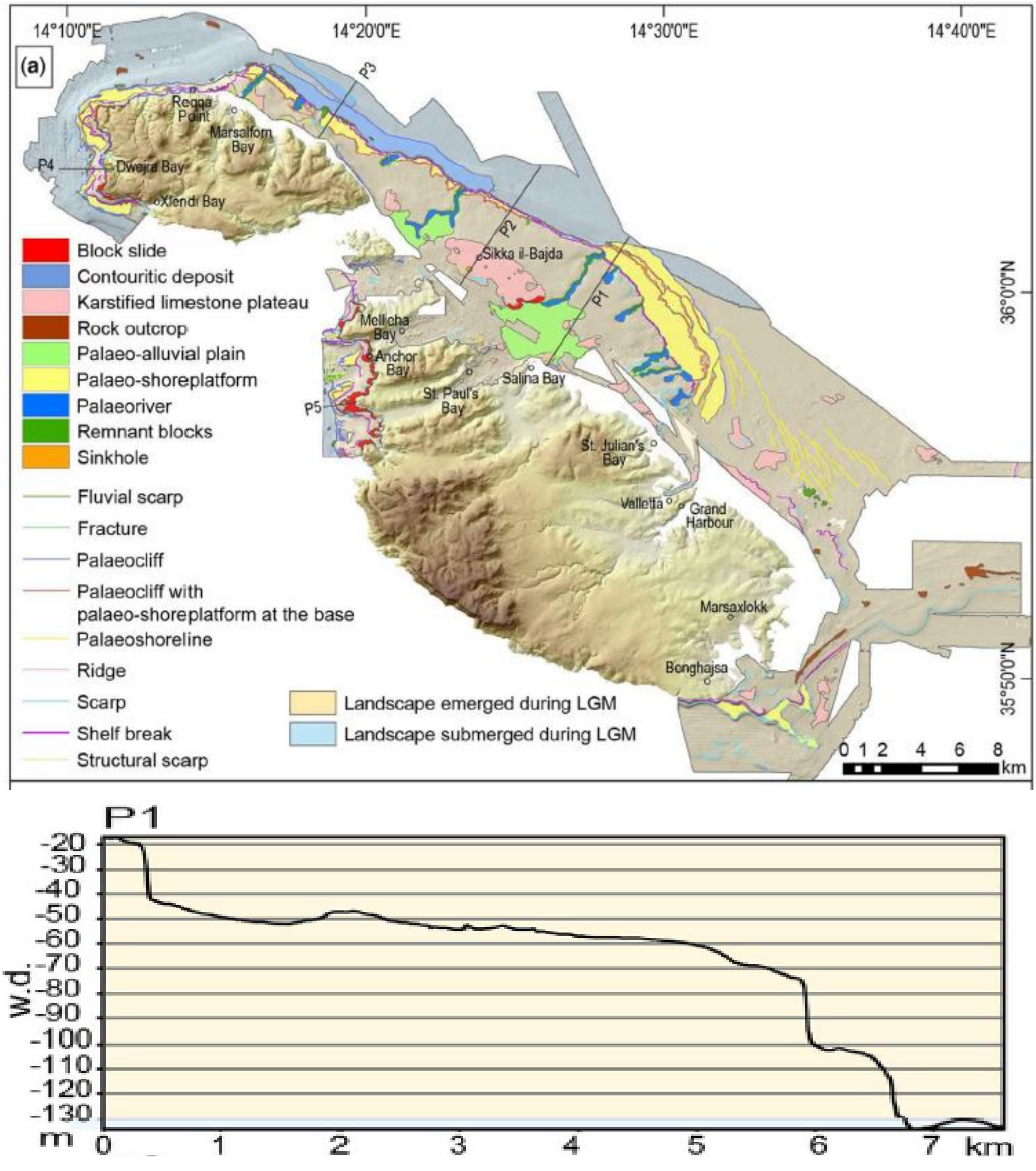


Figure 12: Geomorphological map and Cross-section along the NE continental shelf of Malta (Source: (Foglini et al 2015)

This explains the varied and irregular landscapes, steep scarps, valleys and exposed rock encountered by the PGSM, up to depths of approximately 130m below sea level. This depth marks the external boundary of the emergent coastline during the last Glacial Maximum.

At greater depths there was no exposure during the Pleistocene Glaciations and the sediments encountered are entirely marine, fine deposits such as sand silt and clay.

5.1 Regional Setting

The IC2 cable route is situated on the Malta Plateau, a wide (approximately 10,700 km^2) continental shelf observed as a north-south striking connection between the Hyblean Plateau (south-eastern Sicily) and the Maltese Islands in the central Mediterranean Sea . The Malta Plateau is characterised by relatively shallow water depths, with bathymetry not exceeding 200 m, and a generally smooth, gently sloping seafloor (approximately 2°).

The shelf is bound by the Malta Escarpment to the east and the Gela Basin to the west. The IC2 cable route runs from Malta in the south to Sicily in the north along the western edge of the shelf, with the central portion of the cable route running along the shelf break (Figure 13).

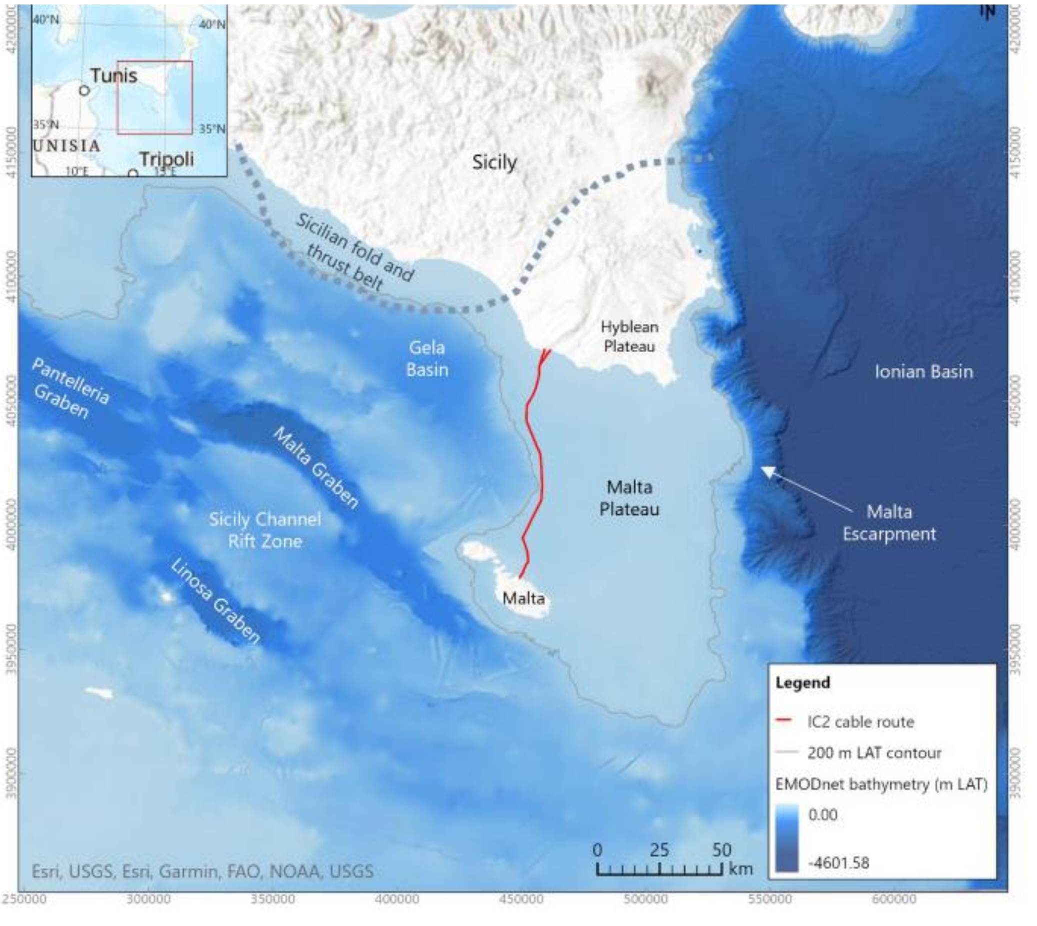


Figure 13: Bathymetric chart Illustrating the IC2 layout with respect to the Malta Plateau and the adjoining Gela Basin

4.3 Geotechnical Unitisation- 8 Geotechnical Units

All 102 geotechnical locations were unitised. Eight (8) geotechnical units and subunits were defined based on geotechnical descriptions, lab testing results and CPT data. Six of these units lie within the Maltese EEZ. The Geotechnical units identified are summarised in Table 8.

Most units/subunits were differentiated based on subtle changes in primary soil type and/or secondary soil constituents, or slight changes in geotechnical properties, such as undrained shear strength or cone resistance (CPT data).

Table 8: Summarised description of the geotechnical units identified along the IC2 route

Geotechnical Unit	Generalised Geotechnical Description	Distribution	Comments
Ia	Loose to very dense coarse SAND with shell fragments and coralline red algae (*Maerl*)	S01 only	Surficial sand present in south of route towards nearshore Malta
Ib	Very loose to dense silty SAND (locally sandy silt)	S10 and S11	Surficial sand present in north of route towards nearshore Italy
II	Extremely low to very low strength silty CLAY to clayey SILT	S03, S04, S08, S09, S10 and S11	Low strength fine grained soil at surface, generally present in deeper water areas
III	Extremely low to low strength sandy SILT, sandy clayey SILT, clayey sandy SILT to sandy silty CLAY. Locally with shell fragments	S02, S03, S04, S05, S06, S07, S08 and S09	Sandy clay/silt layer present across majority of route. Sometimes present at surface, sometimes present beneath Geotechnical Unit II. Generally thin, but locally thicker (up to 1.69 m thick)
IVa	Loose to very dense SAND, silty SAND and sandy SILT	Primarily S05 and S06	Shallow, denser layers of sand/soil present beneath Geotechnical Unit III at surface. Units identified in CPT data. Represent an increase in sand content. Geotechnical Units IVa and IVb were primarily identified in an area of poor to no penetration and recovery through S05 and S06. Geotechnical Unit IVb was also identified in CPT-S10-03 based on similar geotechnical properties/soil conditions in this location
IVb	Interbedded very loose to very dense SAND to silty SAND and low to high strength sandy SILT, clayey SILT to silty CLAY		
V	Extremely low to medium strength clayey SILT to silty CLAY or CLAY. Locally with occasional, isolated sandy beds/horizons	S03, S04, S05, S06, S07, S08, S09, S10 and S11	Low strength fine grained soil generally present below Geotechnical Units II and/or III. Present across majority of route. Difficult to distinguish between Geotechnical Unit II where this unit lies below Unit II. Slight increase in strength with depth. CPT data indicates this unit becomes 'clean clay' at depth
VI	BEDROCK – weak to moderately strong* carbonates (limestone) and/or possible evaporites	S01, S08, S09, S10 and S11	Defined in geophysical data where: ▪ H06/H07 is mapped within 5 m BSF; ▪ Bedrock outcrops are mapped in seafloor features/sediments mapping; ▪ SBP data shows potential for unmapped bedrock at/near seafloor Not directly sampled by geotechnical data, but likely the cause of shallow penetration where bedrock is present within 5 m BSF (S08 to S11)

4.3.1 Geotechnical Unitisation Considerations

The following should be considered regarding the unitisation of geotechnical data:

- Geotechnical Unit VI **(bedrock)** was defined using geophysical data only. Bedrock was not directly sampled by geotechnical data within the offshore survey area. The geotechnical properties (lithology and strengths) of bedrock within the offshore survey area are unknown. Further geotechnical sampling and testing should be completed to fully understand these properties;
- Gravity core locations were unitised based on full sample descriptions and laboratory testing. In some locations, such as gravity core locations through S01, GC-S02-01 and GC-S05-02, full sample descriptions and laboratory testing were not completed due to lack of sample recovery. In these locations, the unitisation was based on the top/bottom gravity core sample descriptions only.
- The material description provided in available CPT logs showed high variability in soil conditions with depth. These material descriptions also appeared contradictory when compared with measured CPT parameters including cone resistance and friction ratio. Engineering judgement was therefore used to unitise CPT locations based on interpretation of cone resistance, friction ratio and calculated relative density and undrained shear strength. Paired gravity core locations also aided interpretation of CPT data;
- Grab samples provide information on surficial sediments only. When unitising grab sample locations, a generic test depth of 0.25 m was assumed;
- Strengths/densities for each geotechnical unit are based on CPT data and indicative geotechnical tests, such as Torvane and Pocket Penetrometer tests. No advance testing was completed on samples.

6. Cable Route Soil Zonation (Source Fugro, PMRS)

6.1 General

The aim of the cable route soil zonation is to spatially delineate and map areas of similar soil conditions and aid identification and mapping of geological hazards.
This section presents the cable route soil zonation for the offshore survey area:

- KP 1.5 to KP 96.5 (HDD alignment 1) and
- Nearshore survey areas were mapped as part of the landfall feasibility assessment report (Fugro, 2023).

6.2 Methodology

Given a lack of clear unit specific correlation between geophysical and geotechnical data, the geotechnical unitisation was the primary driver in the generation of soil zones along the offshore survey area. Unitised geotechnical locations were grouped based on the occurrence of geotechnical units and soil conditions to define soil zones. Geophysical data (SBP data, seafloor sediments mapping and seafloor features mapping and the seismostratigraphic framework were then used to:

- Define the cable route soil zone boundaries;
- Define a zone where bedrock is present (Geotechnical Unit VI);
- Define subzones where bedrock is present outcropping at the seafloor.

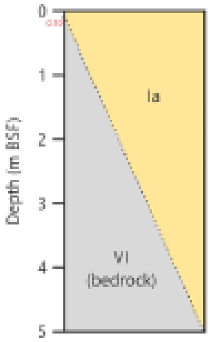
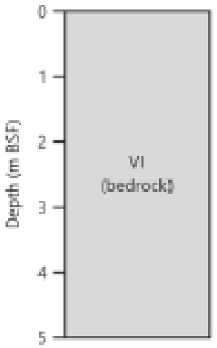
Cable Route Soil Zones and Profiles

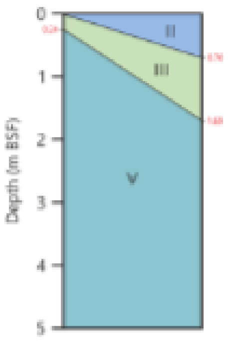
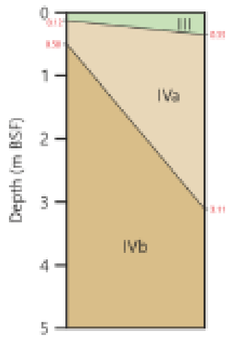
Six (6) main soil zones were defined. Subzones were defined within Zone 1, Zone 3 and Zone 5. Soil zones are summarised in Table 9.

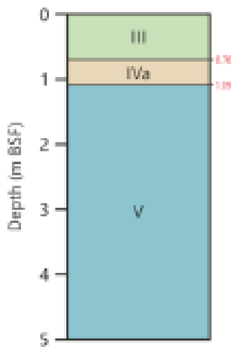
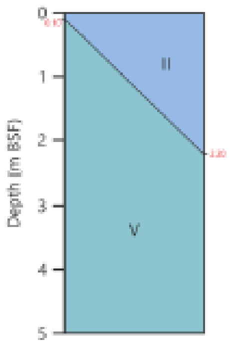
A soil profile to 5 m BSF was derived per soil zone/subzone to depict the stratigraphic relationship and vertical variability in thickness of each geotechnical unit present within that zone/subzone.

Table 9: Description of the cable route soil zones

Table 6.1: Summary of IC2 cable route soil zones

Cable Route Soil Zone	Distribution (KP Range)	Distribution (Data Acquisition Sector)	Soil Profile	Generalised Description
Zone 1a	KP 1.5 to KP 9.5	S01 to S02		Defined by the presence of Geotechnical Unit Ia. Cleaner sands with shell fragments and coralline red algae (*Maerl*) above bedrock. Bedforms locally present at seafloor
Zone 1b	KP 2 to KP 3.5	S01		Localised areas in S01 of bedrock outcropping at seafloor and extending beyond 5 m BSF

Cable Route Soil Zone	Distribution (KP Range)	Distribution (Data Acquisition Sector)	Soil Profile	Generalised Description
Zone 2	▪ KP 9.5 to KP 36.5 (south) ▪ KP 51.5 to KP 69 (north)	▪ S02 to S05 (south) ▪ S06 to S08 (north)		Soil conditions dominated by fine-grained soils (silt/clay) with a sandier unit (Geotechnical Unit III) near surface
Zone 3a (defined at geotechnical locations only)	KP 36.5 to KP 51.5	S05 to S06		Geotechnical Unit IVa and IVb present within 5 m BSF (very dense soil layer). Defined in S05 and S06 only. Represents an increase in sand content within the shallow subsurface. Poor to no penetration and recovery in geotechnical data

Cable Route Soil Zone	Distribution (KP Range)	Distribution (Data Acquisition Sector)	Soil Profile	Generalised Description
Zone 3b (defined at geotechnical locations only)	KP 36.5 to KP 51.5	S05 to S06		Subzone based on a single CPT location in S05 (CPT-S05-01). Subzone represents transitional areas at the boundaries of Zone 3 where Geotechnical Unit IVa/very dense soil layer is thinner
Zone 4	■ KP 69 to KP 95 (HDD alignment 1) ■ KP 95.5 (HDD alignment 2)	S08 to S10 and S11		Represents areas in the north of the offshore survey area where soil conditions are dominated by cleaner, fine grained soils (silt/clay). Differentiated from Zone 2 by the absence of sandier silt/clay sediments (Geotechnical Unit III)

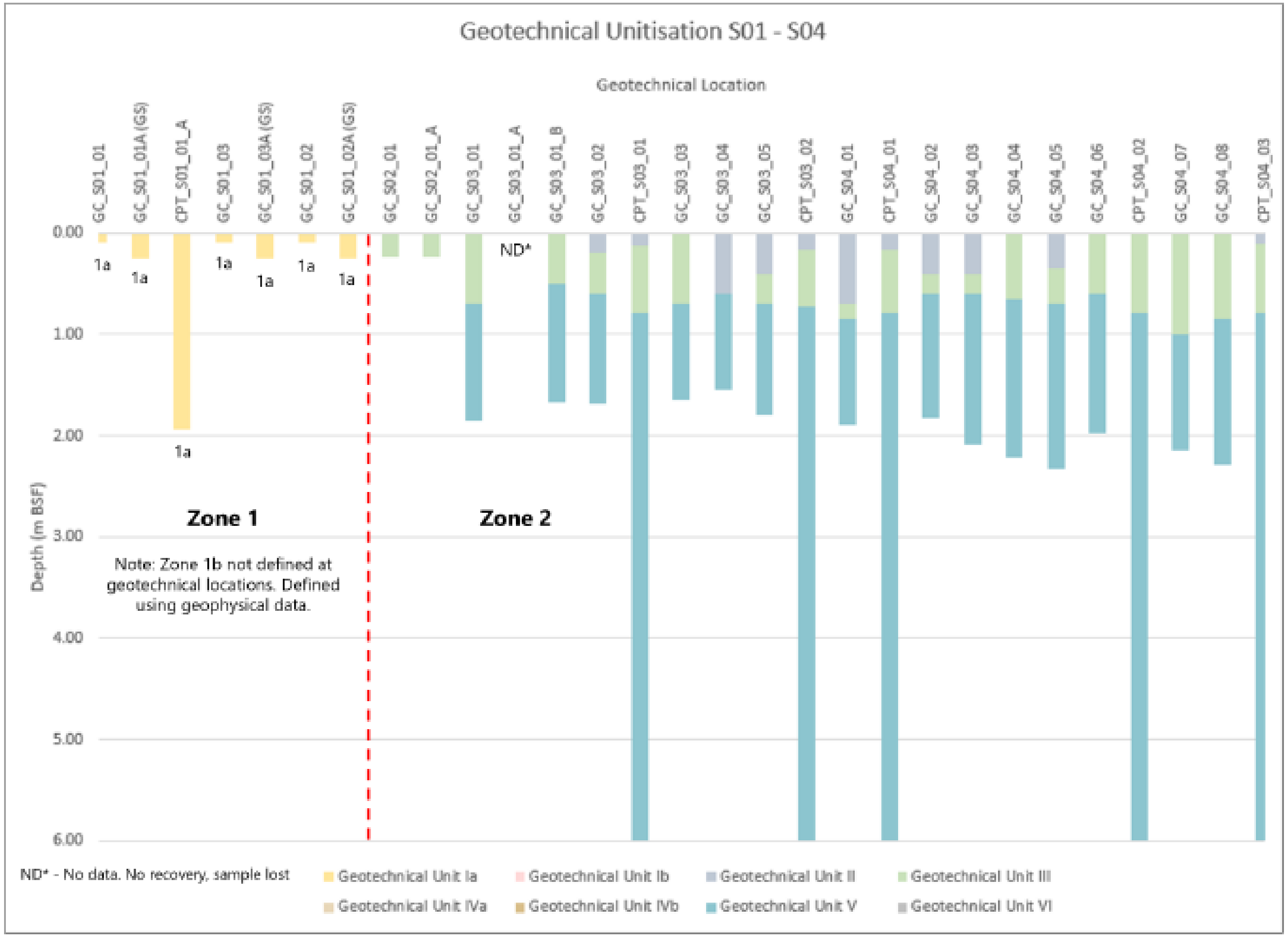


Figure 6.1: Geotechnical unitisation and soil zonation at geotechnical locations in S01 to S04

Figure 14: Geotechnical units derived and respective zonation SO1 to SO4

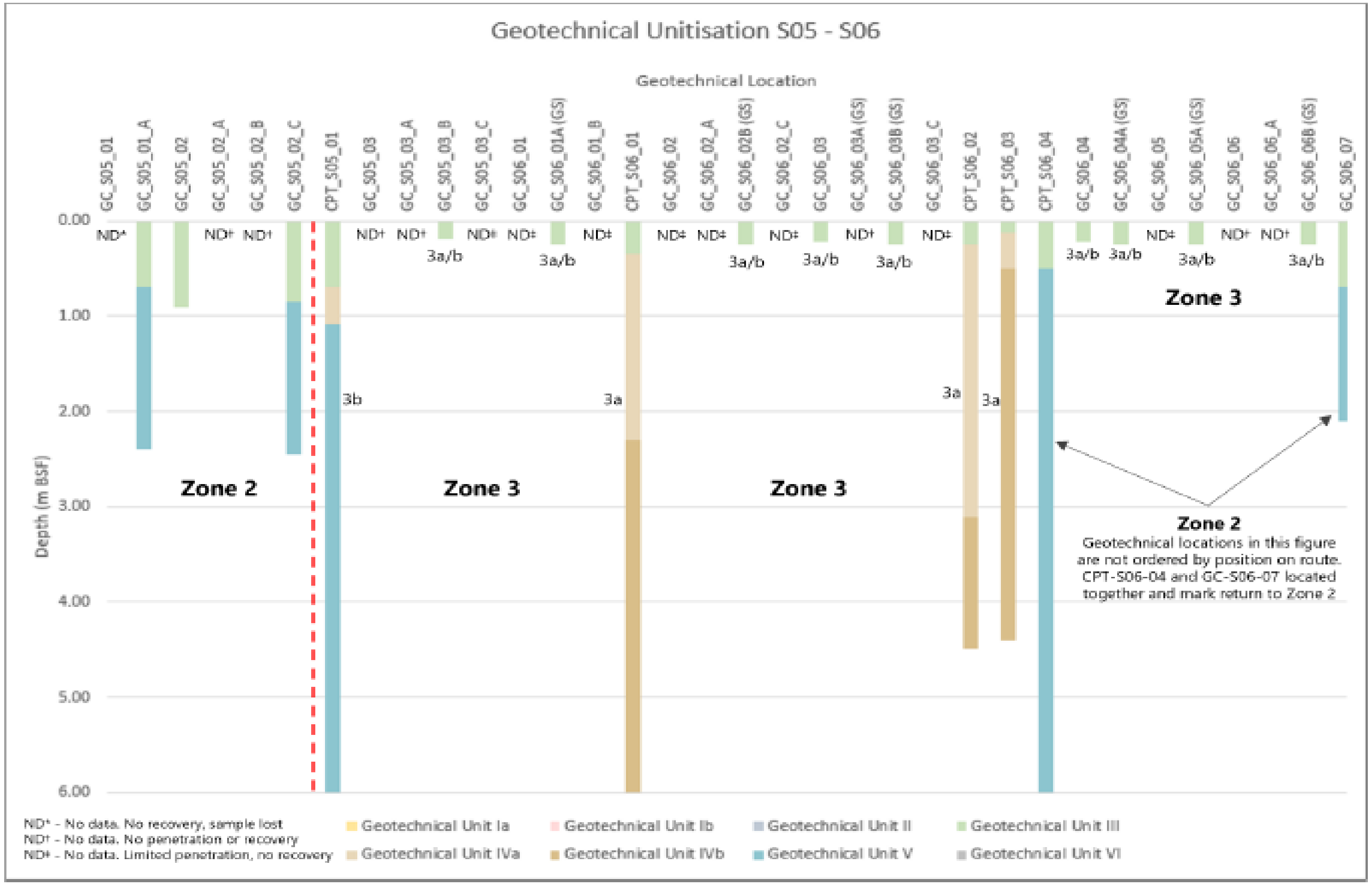


Figure 6.2: Geotechnical unitisation and soil zonation at geotechnical locations in S05 and S06

Figure 15: Geotechnical units derived and respective zonation SO5 to SO6

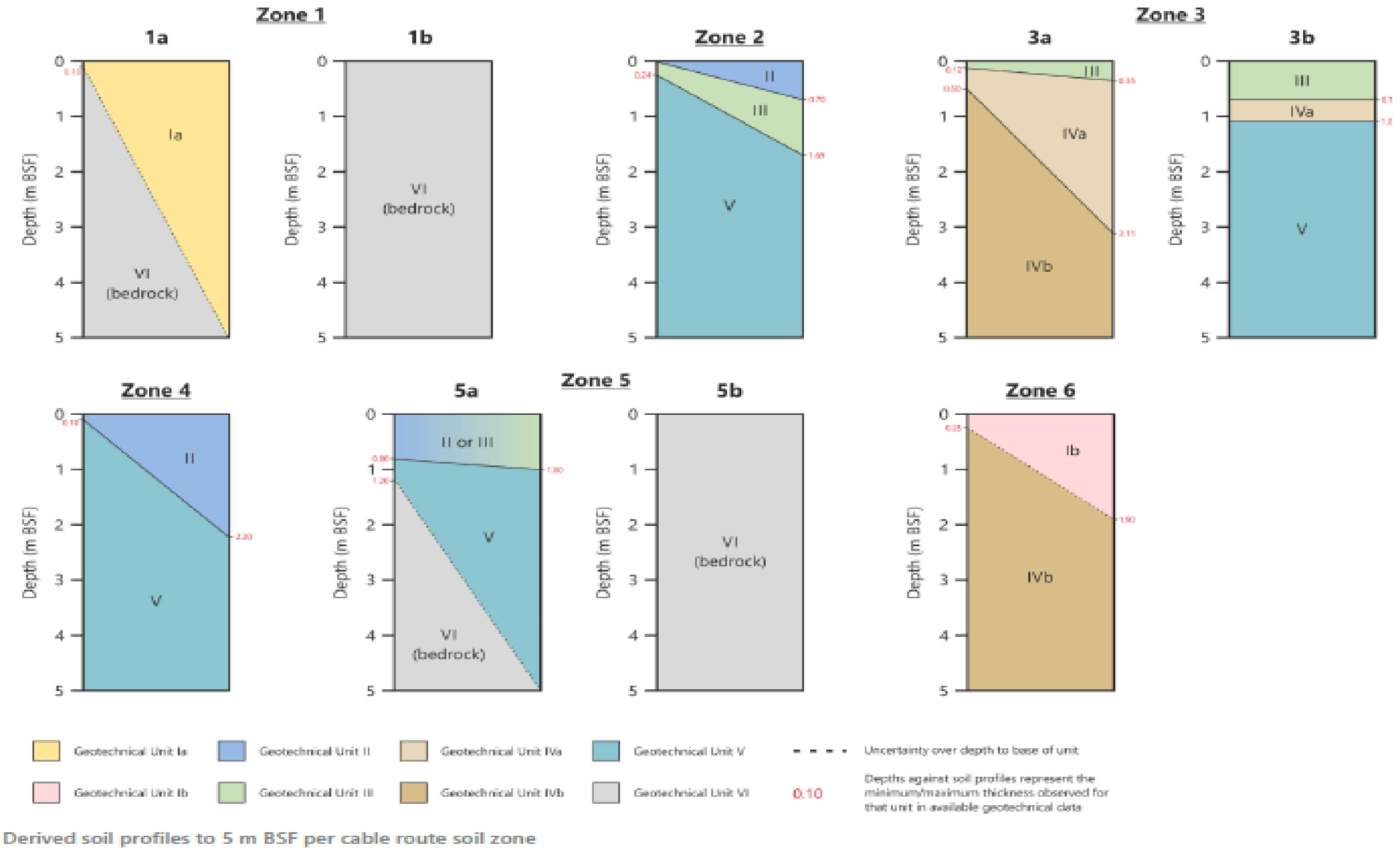


Figure 16: Soil profiles down to 5m below sea floor for each soil zone identified

5.2 Geophysical Survey Results

Bathymetry: along the corridor varies from 0 m at the two landfalls down to -175 m.

Seafloor gradient: The average seafloor gradients are generally less than 2 degrees with the exception of three very distinct areas:

- A rocky coast from the shoreline 0m to -47m bsl.
- Between approximately KP 6.700 and KP 7.800, where a scarp and some channels are present, and
- From approximately KP 77.500 to KP 86.500, where a wide outcrop area is present.

The maximum gradients were observed in correspondence of the scarp in Sectors 1 and 2 (max 50° in some restricted areas).

5.2.1 Geology

Shallow geology across the survey corridor is characterized by the presence of SAND, SILT and CLAY, and locally rocky outcrops. Rocky outcrops and sub outcrops, in the nearshore area, are locally covered by *Posidonia oceanica*. From the Nearshore Malta to the offshore area, eight different seismic units were identified (from Unit A to Unit H).

These units are described in Table 10 below:

Table 10: Seismic Units Description (Nearshore Malta and Offshore area- Unt A to Unit E)

Unit	Reflectors		Reflection Configuration	Geometry and structure	Continuity of internal reflectors	Amplitude distribution	Present in sector	(Checked with preliminary results of Gravity Coring, Grab Samples and CPTs)
	Top	Base						
A	Seafloor	H01	Generally transparent, few weak internal reflectors	Sheetlike, thicker in the south close to Nearshore Malta area. In sector 7 it reaches the minimum thickness, and it became probably just a veneer above Unit B.	Moderate	Medium to high	Nearshore Malta, 1, 2, 3, 4, 5, 6, 7	SAND mixtures, from fine to coarse, presence of Maerl beds in sector 1 and partially in sector 2. SAND and SILT mixtures, locally clayey, locally gravelly in the other sectors. Presence of a veneer of CLAY and SILT on top in sectors 3, 4, 5 6, 7
B	H01 / Seafloor	H02	Almost parallel weak internal reflectors	Mostly continuous internal reflection dipping toward central part of the Sicily Channel. Unit B is thicker in sector 7, reaching almost 20 m, and is thinner in sectors 2 and 5, where its top is eroded by Horizon H01	Moderate to high	Medium	Nearshore Malta (possible), 2, 5, 6, 7, 8	SILT and CLAY mixtures in various percentage. Along Sector 6 this unit was never sampled by gravity coring. CPTs preliminary results indicate the presence of mixed sediments with also SAND.
C	H02 / H01	H03	Parallel internal reflectors, almost transparent seismic aspect	Very faint parallel internal reflectors. The base of the Unit is deeper in Sector 7, where horizon is locally not visible. Thickness of Unit C is generally less than 10 m, except from restricted areas in Sector 7 where it reaches almost 15 m.	Moderate	Low	2, 3, 4, 5, 6, 7, 8	SAND to SILT mixtures, locally clayey
D	H03	H04	Locally evident internal reflector, locally faint or semi transparent	Parallel internal reflectors. The base of the Unit is deeper in sector 7. Locally Horizon H04 is not visible in Sector 7 and in Sector 6. Unit is generally less than 4 m thick, except in sector 8 where it reaches almost 20 m.	Moderate to high	Low to high (Depending also to the depth below the seabed)	3, 4, 5, 6, 7, 8	SAND to SILT mixtures, possibly alternating (Not sampled: minimum depth detected of H04 is 6 m bsb.)
E	H04	H05	Mostly parallel internal reflectors, locally disrupted, slightly undulated	Internal reflectors may vary from faint to medium amplitude and are often discontinuous. The base of the unit is deeper in Sector 4. Unit E thickness is variable between 0 and 20 m (in Sector 4).	Moderate	Low to high (Depending also to the depth below the seabed)	3, 4, 5, 6, 7	SAND, SILT and CLAY mixtures Not sampled:. minimum depth detected of H05 is 11 m bsb

5.2.2 Geophysical Survey Results Nearshore Malta (0m to 1Nautical mile (2.8km)

Geology -Seabed Sediments. Nearshore Malta area is characterized by a very rough seabed, with gradients up to more than 40°. Backscatter is generally high, except for two areas where is medium to low, corresponding to smoother seabed.

The area is characterized by the presence of a rocky seabed with *Posidonia oceanica* meadows. *P. oceanica* appears to be denser in the central part, while in the northeastern zone and in a small area in the southwestern corner several patches with SAND ripples are also present between the Posidonia.

Sediments on the seafloor are interpreted as being predominantly sandy, from fine to coarse with presence of Maerl depending on the area. Some boulders/blocks were also interpreted from the SSS data

Sonar Contacts List

Forty-four (44) SSS contacts not associated with cables/pipelines were detected and divided in three (3) groups:

- one (1) SSS contact was interpreted as anchor scar;
- twenty-nine (29) SSS contacts were associated and interpreted as boulders;
- fourteen (14) SSS contacts were interpreted as unknown objects.

Magnetic anomalies

Fifteen (15) magnetometer anomalies were detected. These anomalies which are not associated with cables/pipeline, were divided in two (2) groups:

- eleven (11) magnetometer anomalies were interpreted along rock edge as possible debris
- four (4) anomalies were classified as unknown objects.

Seabed Sediments

Within the Nearshore Malta only one unit was recognized together with limited areas that were observed between the rocky outcrops with encrusted *Posidonia oceanica*. This unit (Unit A) is expected to comprise of SAND, lying directly over the rocky unit -lower Coralline Limestone Fm- that outcrops on the coast.

Within Sector 1 only Unit A is visible, and it comprises mostly sandy sediments. Unit A lies directly on a rocky outcrop in the area closer to the coastline. Toward the **north, Unit B is not** visible due to acoustic signal absorption related to the presence of coarse sediments.

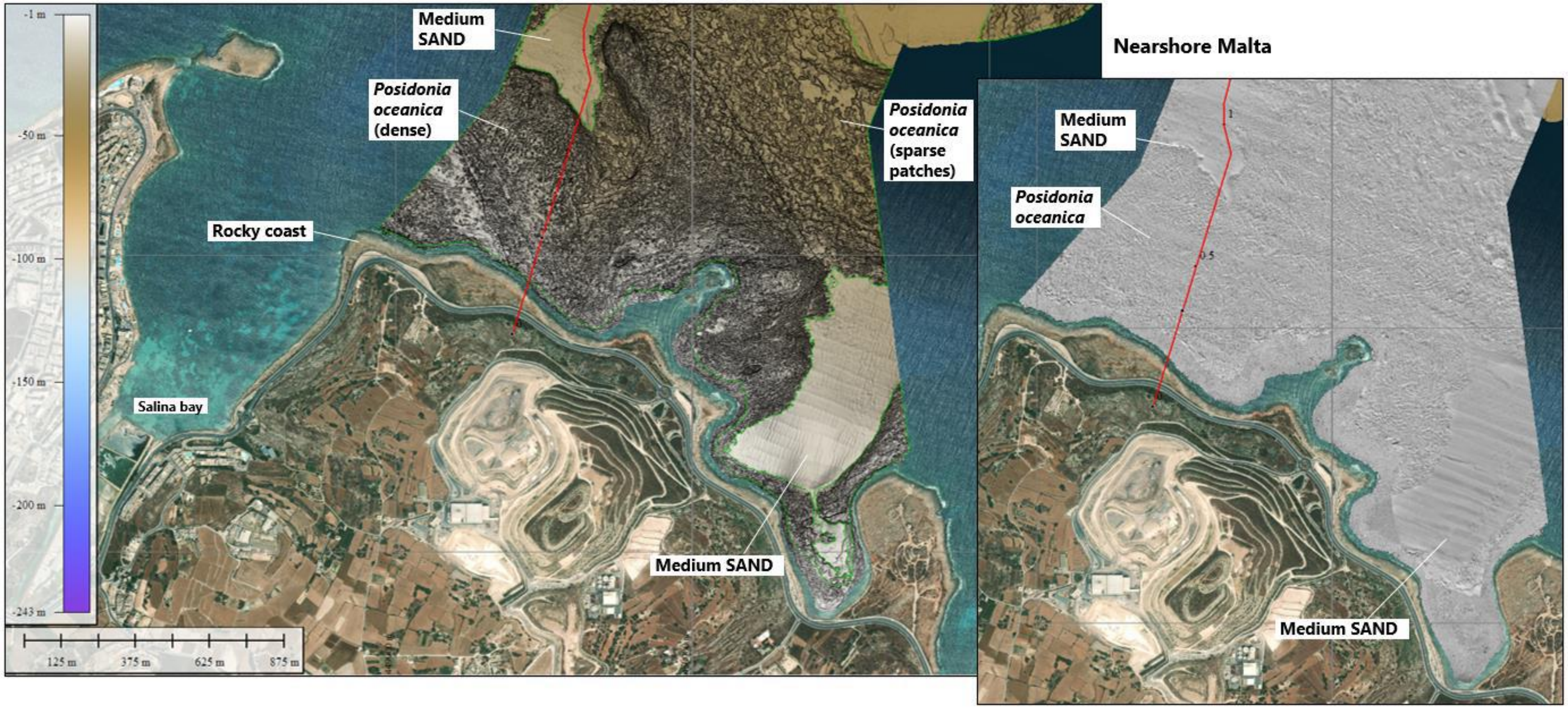


Figure 17: Typical rock/sediment encountered in Malta Nearshore area

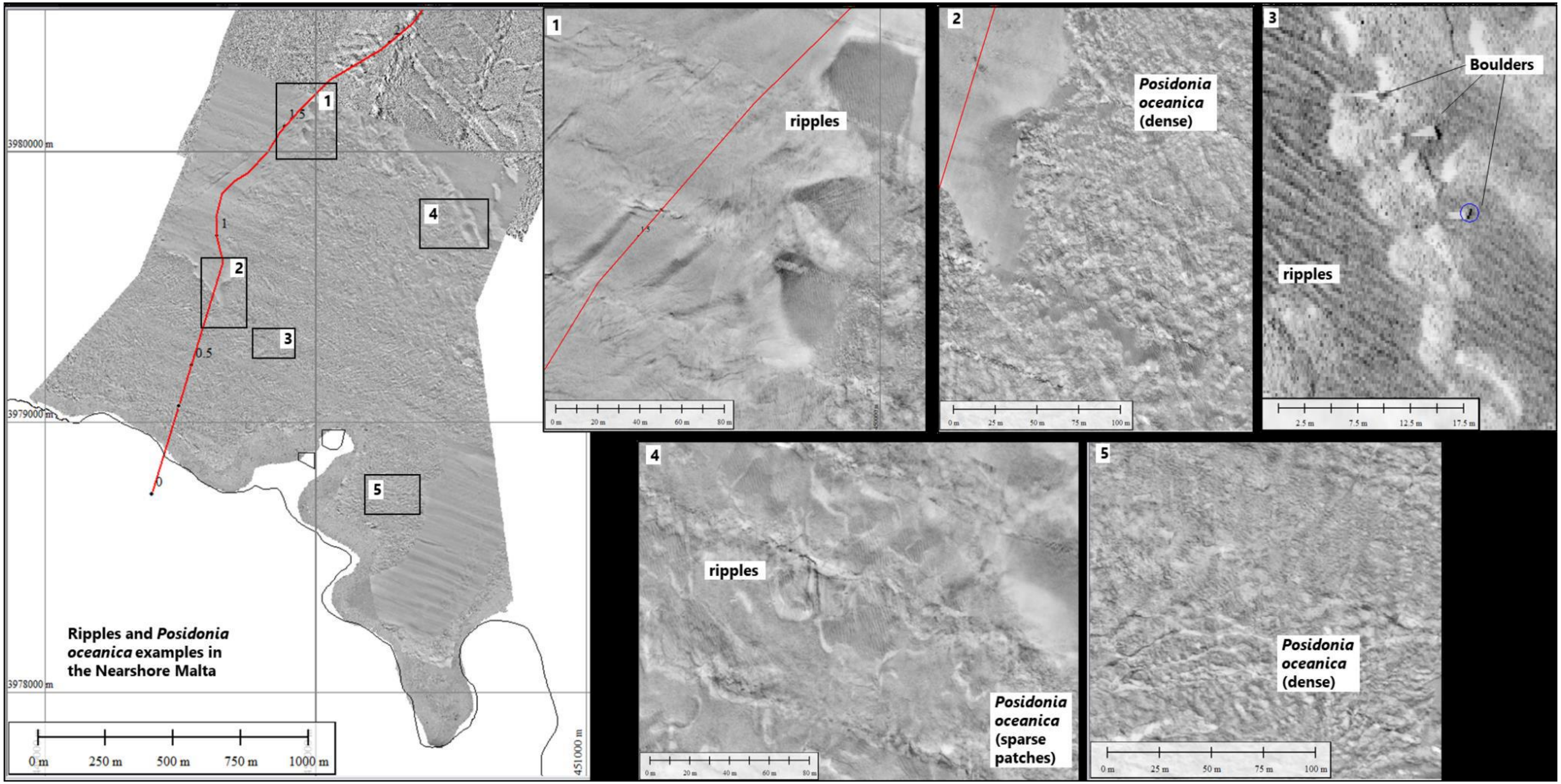


Figure 18: Examples OF Posidonia Oceanica in the nearshore Malta segment

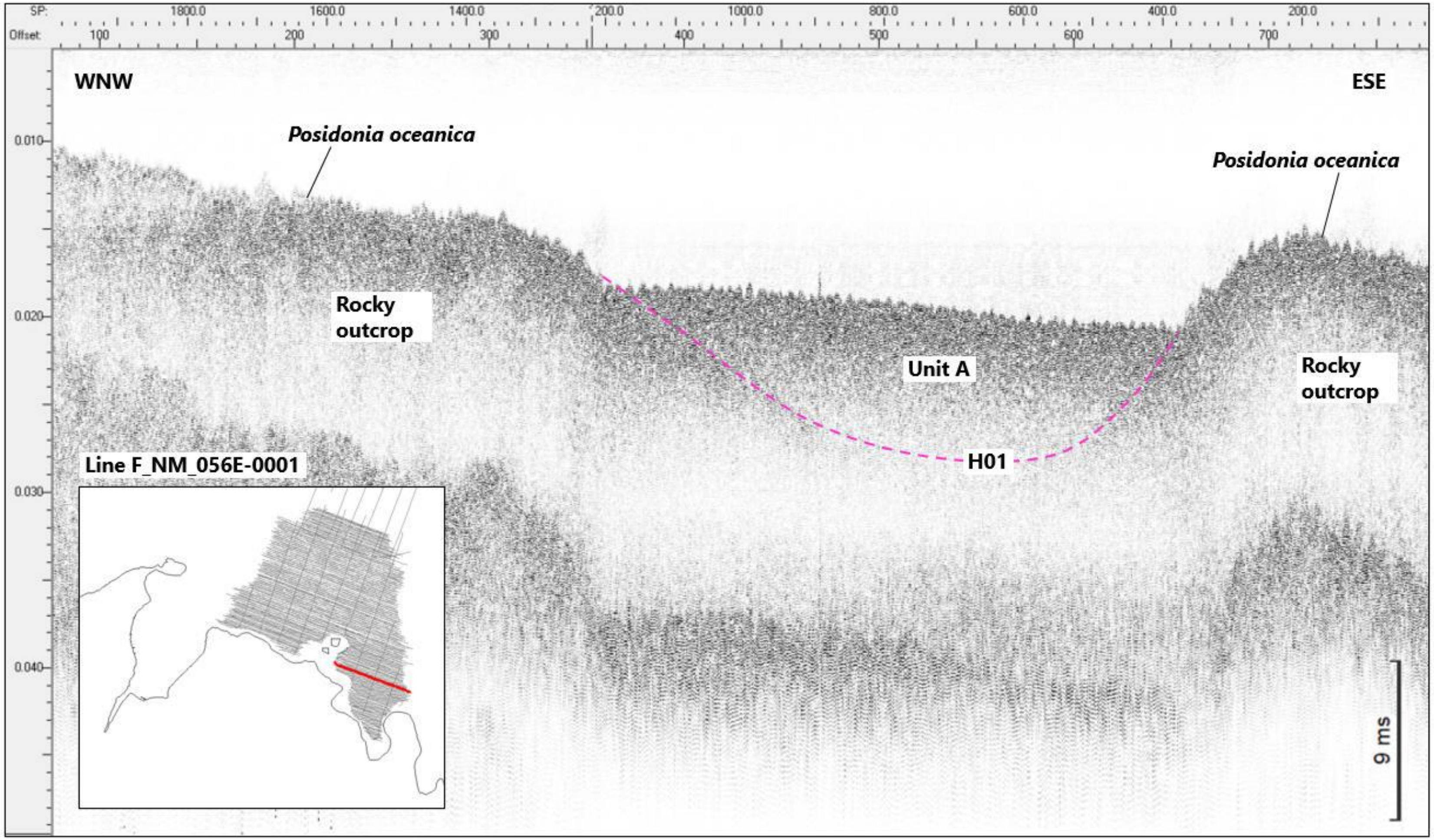


Figure 19: Sub-bottom profiler line showing Unit Aa (sand) in a buried channel, rocky outcrop covered by Posidonia oceanica and horizon HO1

5.2.3 Geophysical results and Interpretation Offshore Malta-Sicily

The IC2 Route covered in this part of the study covers a distance of approximately 61 km starting from approximately 3km from the Ghallis coastline to the EEZ boundary between Malta and Italy.

A description of the offshore sectors follows:

Sector -1 Seabed Sediments and Bathymetry

Sector 1, between KP 1.690 and KP 7.005, is characterized by a generally low gradient area, apart from a smooth break of slope NW-SE oriented, in the northern part, with a gradient of approximately 4°. Depths varies from approximately -45 m to -95m.

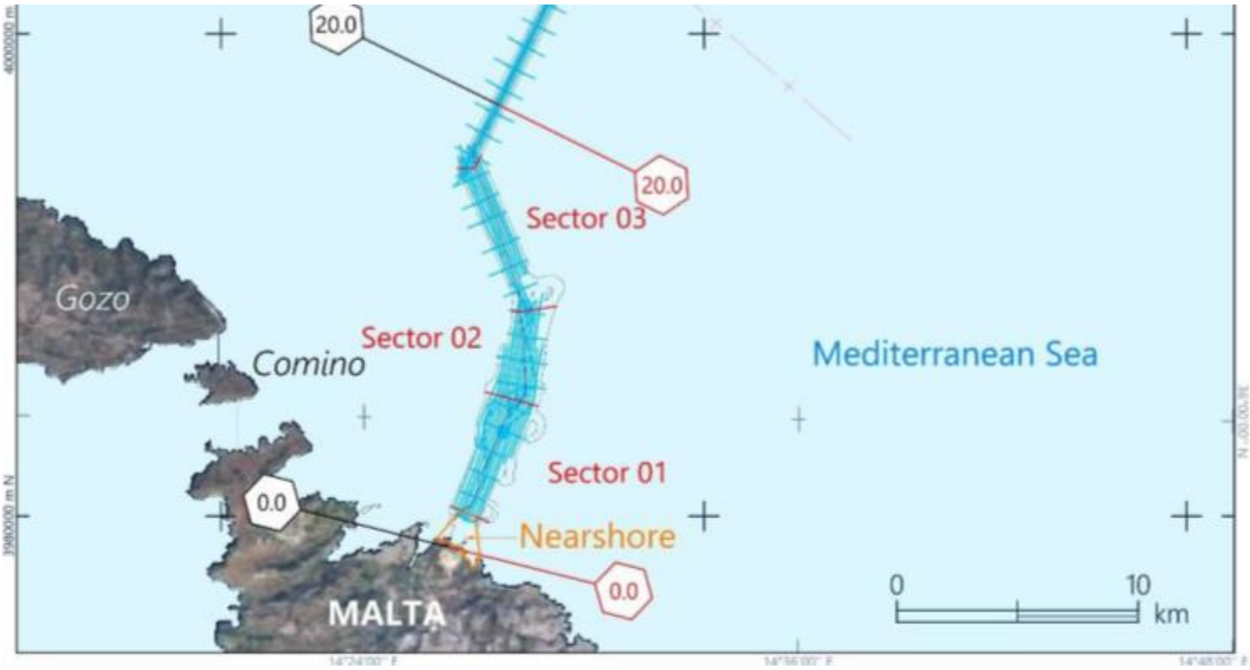


Figure 20: Map showing the location of Sector 1 on the IC2 route

Seabed Sediments

In the southern part there are several patches of medium SAND, alternating with coarser SAND with presence of sparse Maerl. From KP 2.577 medium SAND disappears, and only coarse SAND with shell fragments and coralline red algae (Maerl) are present (as per geotechnical grab samples), with ripples and megaripples. Maerl becomes predominant from approximately KP 5.700, covering the entire seafloor toward the north. Some mound areas were also observed, with very dense algae on top, possibly encrusted. In the western part of this sector a channel run approximately parallel to the proposed route, curving toward the NE in the northward. Another smaller channel is present to the east, cutting into the major break of slope present between Sector 1 and Sector 2.

Some small depressions (possibly interpreted as pockmarks) were observed close to the main scarp in the northern part of Sector 1. A few patches of debris were also interpreted from SSS data.

Unexploded Ordnance - UXO

Five targets interpreted as probable UXO objects were interpreted from the ROV videos. These are present in the north-eastern part of this sector.

Sector 2 Seabed Sediments and Bathymetry

Water depth 95m to 150m
Sector 2, between KP 7.005 and KP 10.800, is characterized by an area with a very rough seafloor in the southern part of the sector, then it becomes smoother and with low gradients (approximately less than 3°). Depths varies from approximately -95 m to -150 m.

The area between KP 6.780 (Sector 1) and KP 7.715 (Sector 2) is characterized by a rough seabed, with several break of slopes and locally high gradients (up to more than 30°). Within this zone medium to high backscatter was observed. It was interpreted with the presence of predominant Maerl, coarse SAND and blocks on the seafloor, confirmed by geotechnical grab samples and ROV video data.

In the flat area that follows the route corridor toward the north, the backscatter is generally medium to low, and there are large areas with small depressions interpreted as pockmarks. Apart from these, only a few patches of debris are present on the seafloor. Sediments in this area comprise fine to coarse clayey SAND with shell fragments and fine gravel.

Unexploded Ordnance -UXO

Within this area several UXO objects were also observed.

Sector 3 to Sector 6 (EEZ Boundary at approx. 52.2km) -Seabed Sediments and Morphology

Bathymetry: Depths varies from approximately -150 m to -160m.

These sectors, between KP 10.800 and KP75.000, are characterized by smooth seafloor and low gradients (approximately less than 1°).

Seabed Sediments

This section of the corridor is characterized by generally medium to low backscatter, interpreted as CLAY and SILT mixtures, locally sandy, locally with shell fragments.

The main natural features on the seafloor are large areas with several depressions, interpreted as pockmarks. Several patches of debris are also present.

Moreover, two aircraft were interpreted from SSS and video data from ROV. Close to these wrecks, anthropic debris and locally UXO objects such as possible unexploded bombs.

Along these sectors, areas with trawl scars related to fishing activities were observed.
These sectors are crossed by several cables, that were generally identified by magnetometer data, locally SSS data too, indicating cables laying on the seabed.

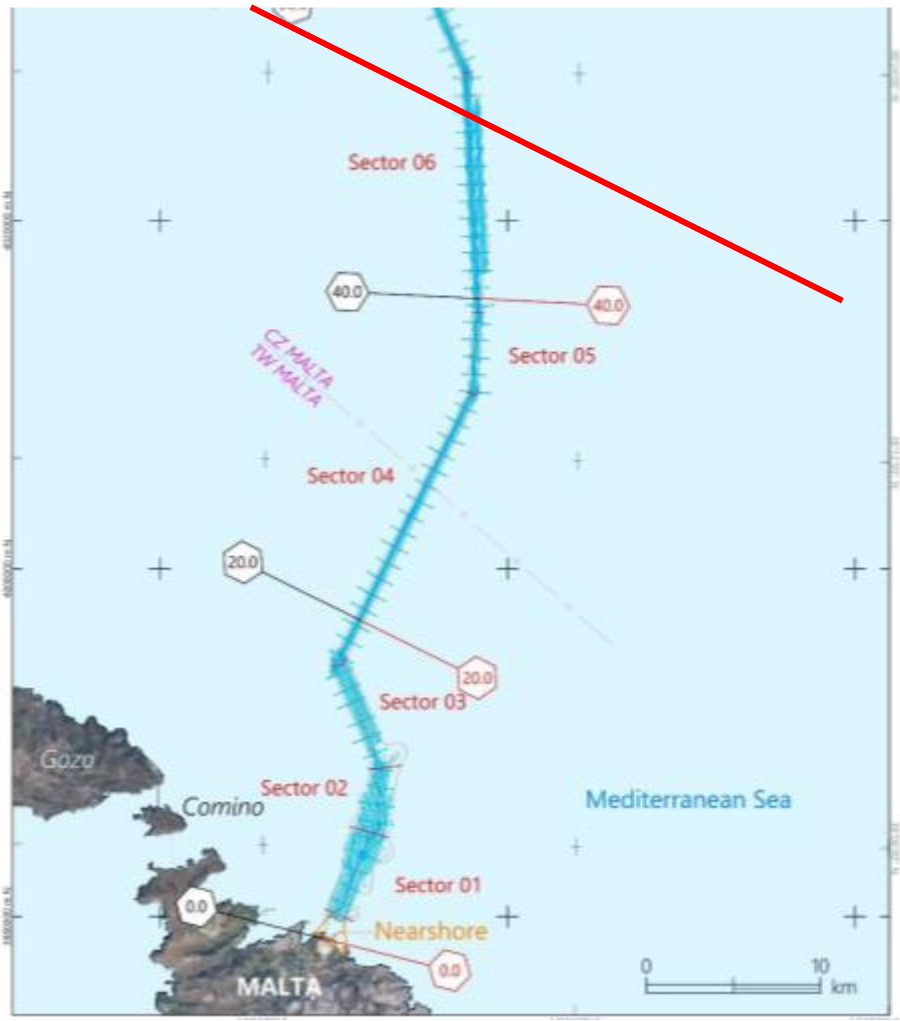


Figure 21: Map showing sectors 1 to 6 on the IC2 Route. Note that the EEZ Malta/Italy boundary lies in Sector 6.

Sonar Contacts

SSS data were acquired along the entire survey corridor and the extended work areas. The data was processed and interpreted in order to isolate backscatter areas related to the presence of different sediments on the seafloor, and to pick contacts.
Within the Offshore Malta-Italy area two hundred and four (204) SSS contacts not associated with cables/pipelines were detected and divided in seven (7) groups:

- two (2) SSS contacts were interpreted as airplane wrecks,
- one (1) fishing net,
- four (4) pockmarks,
- two (2) rocky outcrops,
- two (2) Sea mound,
- six (6) bubbles in water column,
- while the other one hundred and fifteen (187) SSS contacts were classified as unknown objects.

2.3.4 Magnetic anomalies

Magnetometer was operated on the same pass as SSS. The magnetometer data could be affected by the vertical fluctuation of the instrument in the water column.

Two hundred and eleven (211) magnetometer anomalies were detected within the Offshore Malta-Italy survey corridor. These anomalies not associated with cables/pipeline, were divided in seven (7) groups:

- five (5) magnetometer anomalies were associated and interpreted as airplane wrecks,
- thirteen (13) debris,
- one (1) depression,
- two (2) rocky outcrops,
- five (5) pockmarks,
- five (5) Sea mound/Bioconstructions,
- while the other ninety-one (91) anomalies were classified as unknown objects.

For the complete list of magnetic anomalies see 21.

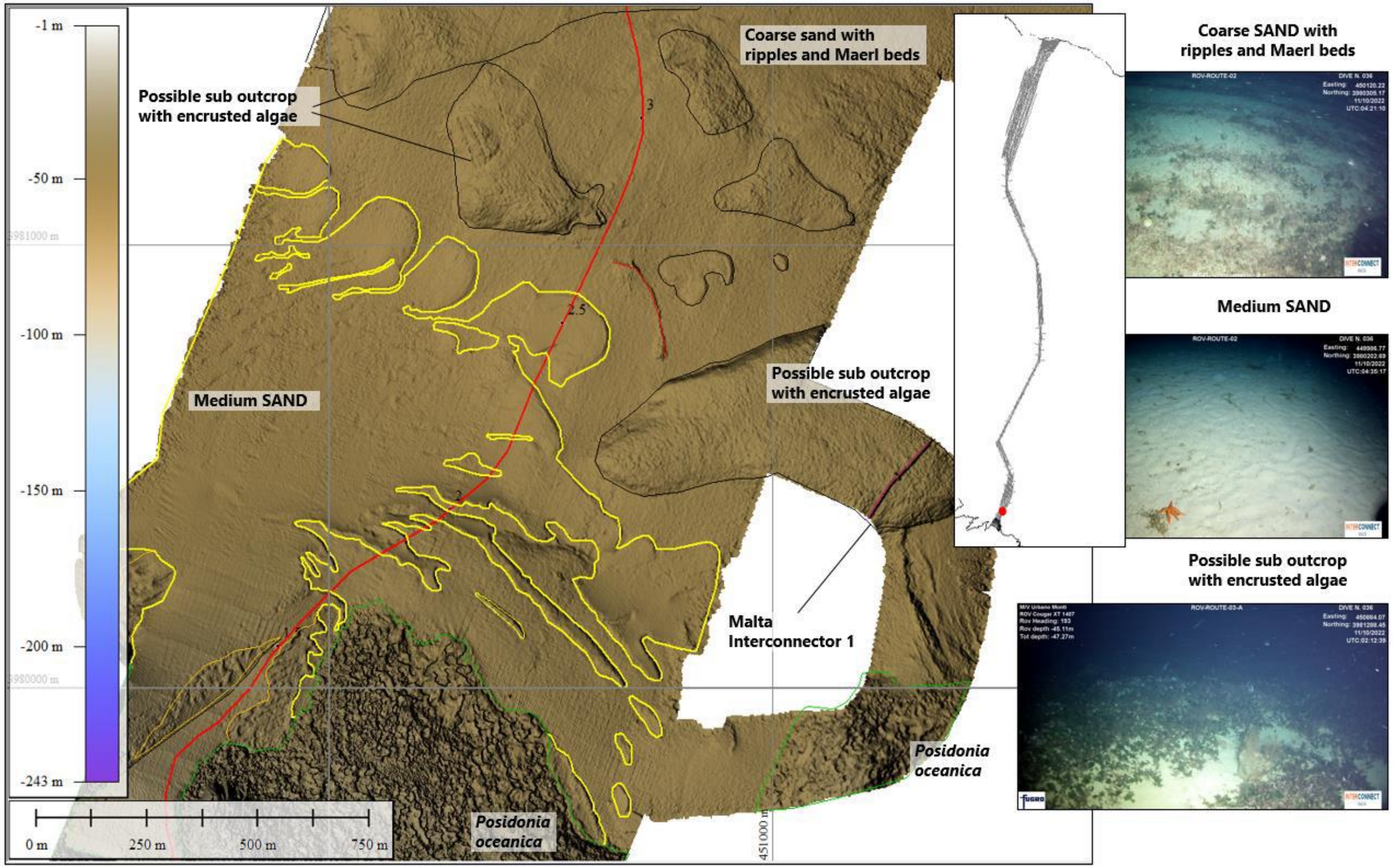


Figure 22: Seabed Geology and Geomorphology-Map showing distributon of rock outcrops, sand and Posidonia beds together with ROV seabed pictures in the Malta nearshore sector

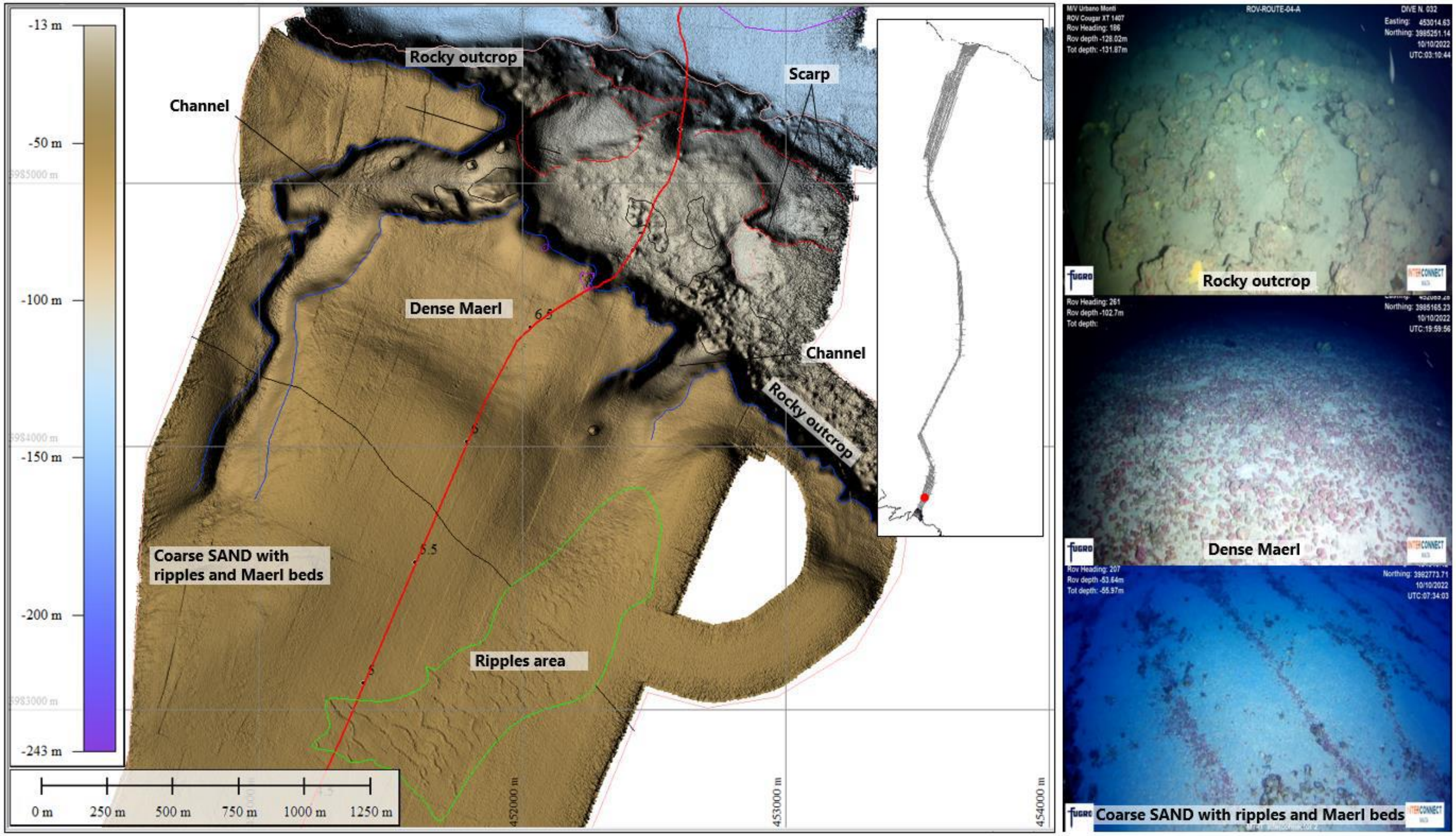


Figure 23: Geology and Geomorphology Sector 1 and Sector Multibeam Eco Sounder and ROV data- Map showng distributon of rock outcrops, sand and Posidonia beds together with a channel at the ternminaton of the shore platform.   These are illustrated with ROV seabed pictures

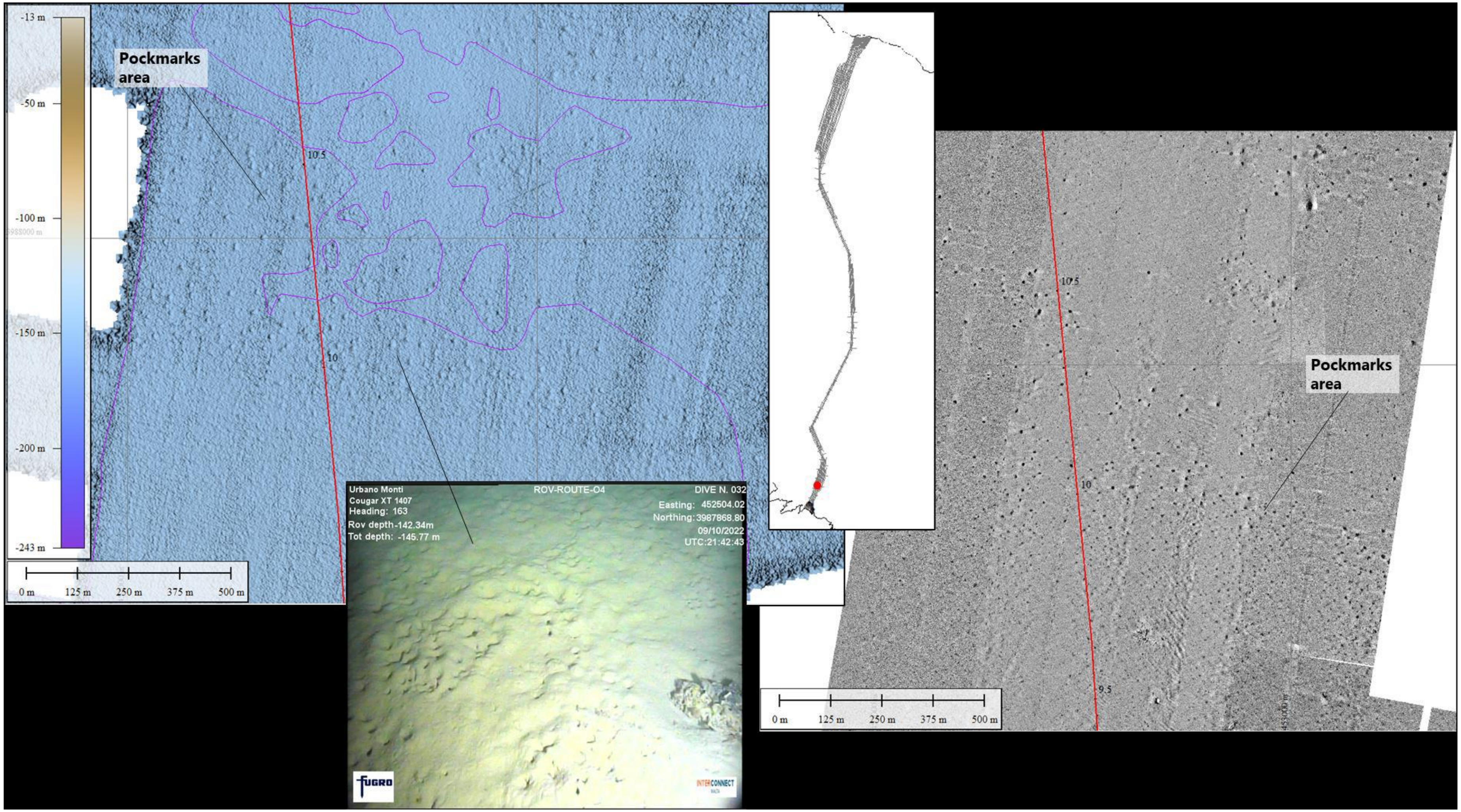


Figure 24: KP 9 to 10.5m Geology and Geomorphology Malta Sector 2; Pock Marks seen from Multibeam echo Sounder and Side Scan Sonar Data

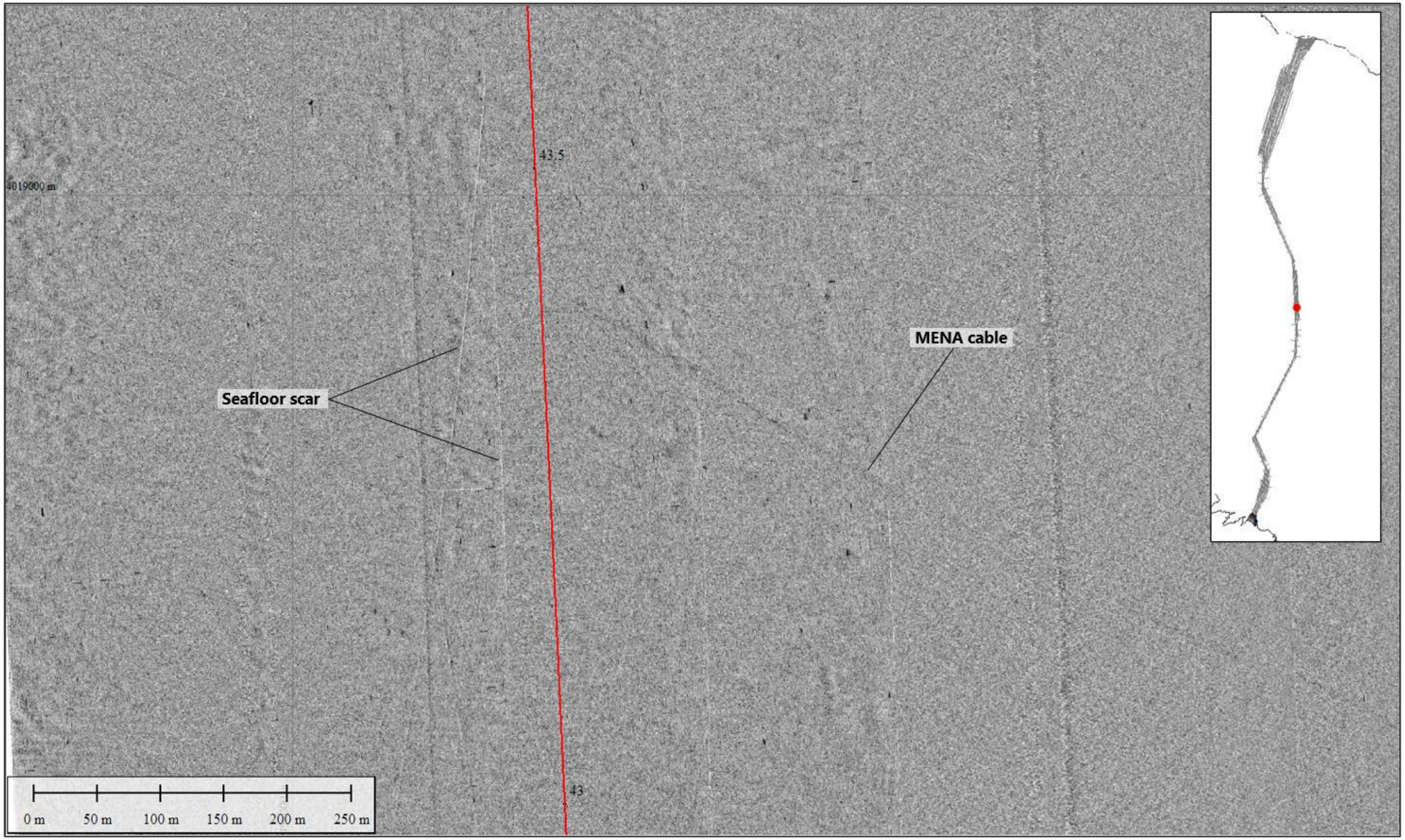


Figure 25: KP43-KP44: Sidescan Sonar Data showing fine seabed sediments- A Cabel and seafloor scars

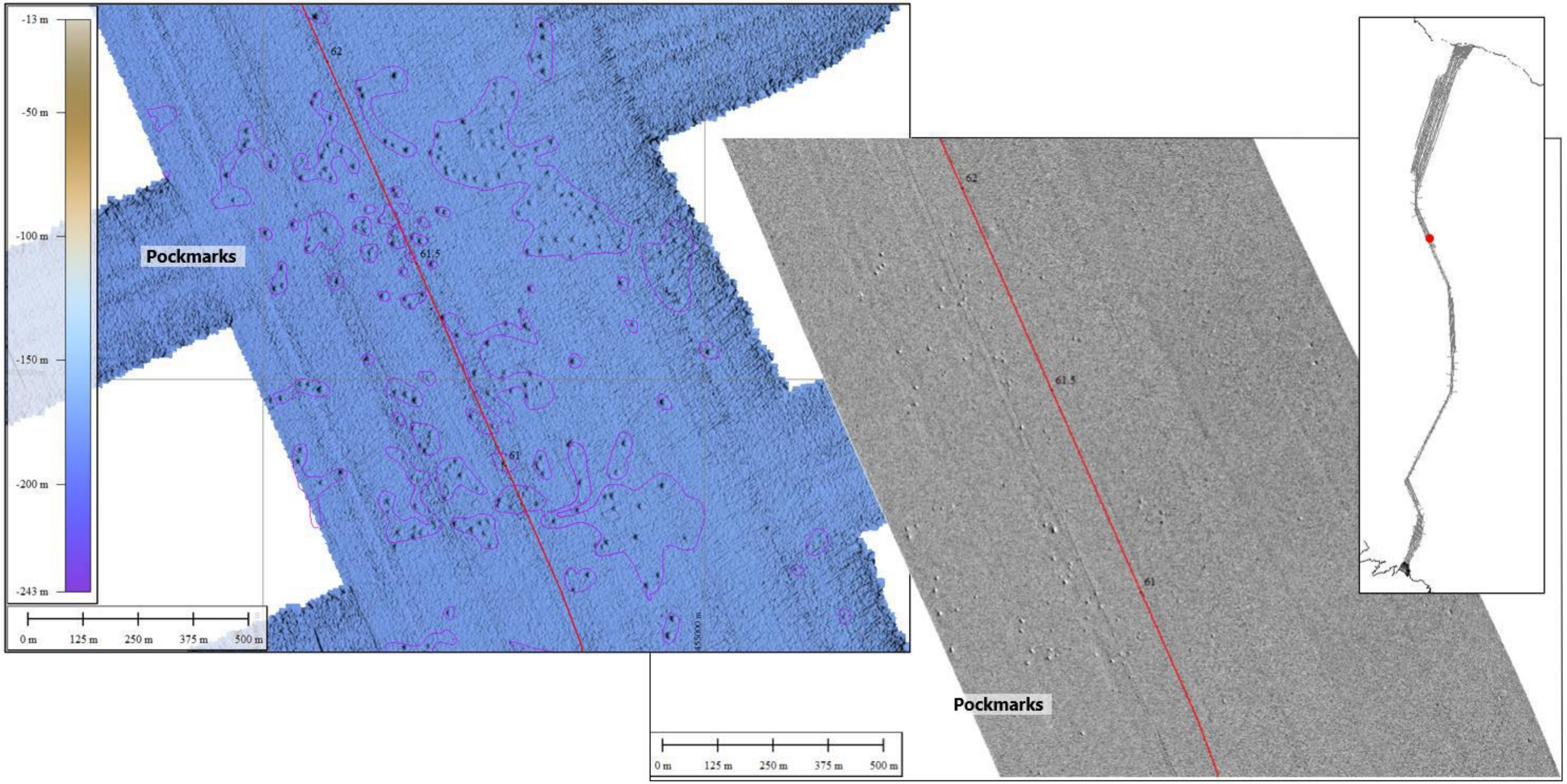


Figure 26: Multi Beam Echo Sounder and Sidescan Sonar data showng a Fine example of large pockmarks

5.2.4 Shallow Stratigraphy

The shallow stratigraphy has been compiled from the interpretation of the Sub-bottom profiler data.

Useful acoustic penetration of maximum 45 ms TWTT (2-way travel time) or approximately 36 m bsb was generally achieved over the survey area. Vertical resolution of the data is estimated less than 0.5 m for sub-bottom profiler; soil layers thinner than this may not have been detected. The line spacing is approximately 150 m; sub-seafloor features smaller than 150 m and present between the lines may not have been detected. Depths and positions of soil layers between survey lines are based on interpolation, the reliability of which depends on the complexity of the geology. The sub-seafloor depths were estimated using an assumed acoustic velocity of 1600 m/s, which is considered reasonable for the interpreted sediment types.

Shallow stratigraphy was cross checked with the preliminary results of gravity coring, grab samples and CPTs acquired during the geotechnical survey.

Along the survey corridor eight (8) different units (Unit A to Unit H) were identified, mostly deepening toward the central part of the Sicily Channel, their base being generally deeper in Sector 7. Of the eight units 6 have been identified in the Maltese EEZ. They are described in Table 11 and illustrated in Figure 27 and Figure 28).

Sector 1: Within Sector 1 only Unit A is visible, and it comprises mostly sandy sediments. Unit B, below, is not visible due to acoustic signal absorption related to the presence of coarse sediments on the seafloor.

From Sector 2 on the Maltese Continental shelf to Sector 8 and the southern part of **Sector 9 on the Italian Continental shelf**, the stratigraphy sequence is mostly visible everywhere, from Unit A to Unit F, depending on the thickness of each unit and the signal.

The sediments show an alternance of medium and low amplitude internal reflectors, **consisting in SAND, SILT and CLAY mixture**s in different percentages.

Table 11: Description of the stratigraphy of sector 01 to Sector 06

Unit	Reflectors		Reflection Configuration	Geometry and structure	Continuity of internal reflectors	Amplitude distribution	Present in sector	(Checked with preliminary results of Gravity Coring, Grab Samples and CPTs)
	Top	Base						
A	Seafloor	H01	Generally transparent, few weak internal reflectors	Sheetlike, thicker in the south close to Nearshore Malta area. In sector 7 it reaches the minimum thickness, and it became probably just a veneer above Unit B.	Moderate	Medium to high	Nearshore Malta, 1, 2, 3, 4, 5, 6, 7	SAND mixtures, from fine to coarse, presence of Maerl beds in sector 1 and partially in sector 2. SAND and SILT mixtures, locally clayey, locally gravelly in the other sectors. Presence of a veneer of CLAY and SILT on top in sectors 3, 4, 5 6, 7
B	H01 / Seafloor	H02	Almost parallel weak internal reflectors	Mostly continuous internal reflection dipping toward central part of the Sicily Channel. Unit B is thicker in sector 7, reaching almost 20 m, and is thinner in sectors 2 and 5, where its top is eroded by Horizon H01	Moderate to high	Medium	Nearshore Malta (possible), 2, 5, 6, 7, 8	SILT and CLAY mixtures in various percentage. Along Sector 6 this unit was never sampled by gravity coring. CPTs preliminary results indicate the presence of mixed sediments with also SAND.
C	H02 / H01	H03	Parallel internal reflectors, almost transparent seismic aspect	Very faint parallel internal reflectors. The base of the Unit is deeper in Sector 7, where horizon is locally not visible. Thickness of Unit C is generally less than 10 m, except from restricted areas in Sector 7 where it reaches almost 15 m.	Moderate	Low	2, 3, 4, 5, 6, 7, 8	SAND to SILT mixtures, locally clayey
D	H03	H04	Locally evident internal reflector, locally faint or semi transparent	Parallel internal reflectors. The base of the Unit is deeper in sector 7. Locally Horizon H04 is not visible in Sector 7 and in Sector 6. Unit is generally less than 4 m thick, except in sector 8 where it reaches almost 20 m.	Moderate to high	Low to high (Depending also to the depth below the seabed)	3, 4, 5, 6, 7, 8	SAND to SILT mixtures, possibly alternating (Not sampled: minimum depth detected of H04 is 6 m bsb.)
E	H04	H05	Mostly parallel internal reflectors, locally disrupted, slightly undulated	Internal reflectors may vary from faint to medium amplitude and are often discontinuous. The base of the unit is deeper in Sector 4. Unit E thickness is variable between 0 and 20 m (in Sector 4).	Moderate	Low to high (Depending also to the depth below the seabed)	3, 4, 5, 6, 7	SAND, SILT and CLAY mixtures Not sampled:. minimum depth detected of H05 is 11 m bsb
F	H05	H06 (?)	Transparent unit – faint reflector	This unit is visible only locally, below H05, with no base visible.	Moderate	Low	3, 4, 5	SILT – CLAY mixtures Not sampled: minimum depth of H06 in sectors 3,4 and 5 is >21 m bsb

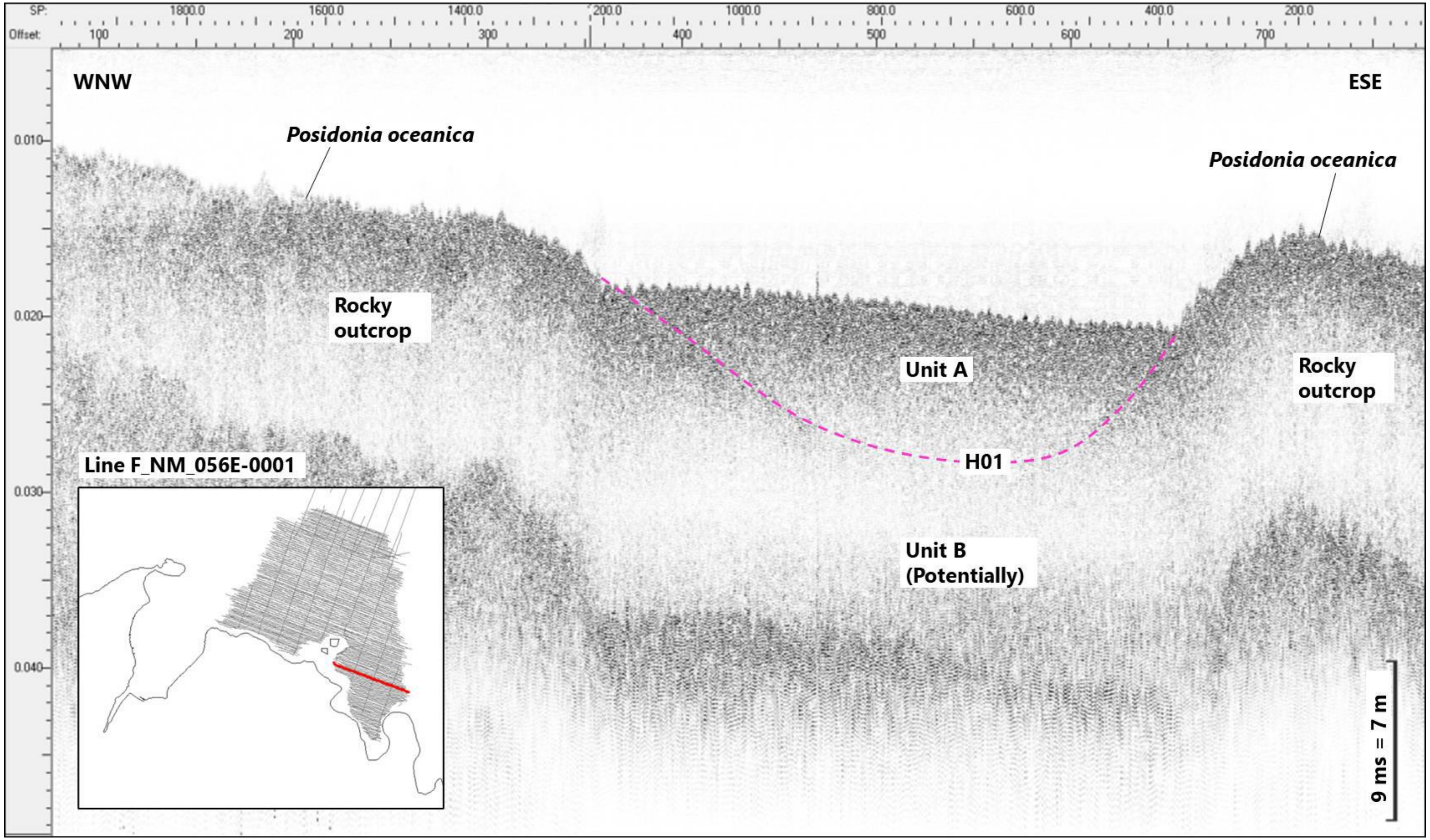


Figure 27: Typical Sub-bottom Profiler seismic section showing a buried channel at the mouth of Qalet Marku representing the submarine extension of Wied ta'Kieli

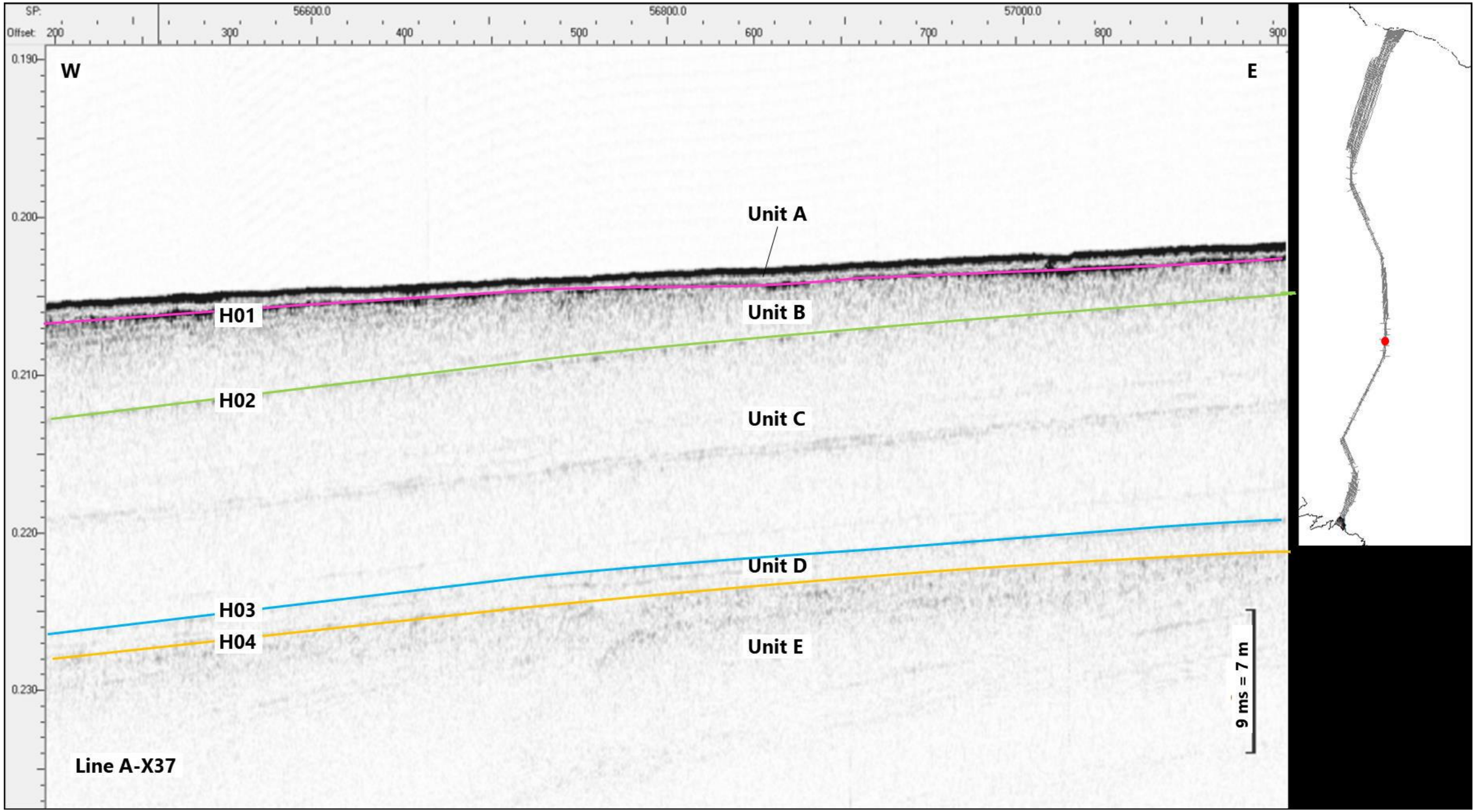


Figure 28: Another example of a Sub-bottom Profiler section - LIne-AX37 ***in Sector 6***

5.2.5 Shallow gas and other geohazards

5.2.5.1 High Impedance Reflectors

Along the survey corridor, some patches were noticed on the SBP data showing high amplitudes compared with the remaining part of the horizons (Figure 29). These high amplitudes were observed extensively in correspondence of Horizon H01 (more present in Sectors 3 to Sector 6), and in small patches on H03 and H04 (Sector 3 and Sector 4).

These areas could be related to the presence of coarser sediments, or to encrusted levels due to the presence of interstitial fluids (High Impedance reflectors: HIR).

The high impedance reflectors are a geophysical proxy of hydrocarbon (HC) fluid migration and may be associated to Methane-derived authigenic carbonate (MDAC), oil, gaseous fluid and gas hydrate occurrence (Figure 31).

Patches of positive high-amplitude anomalies are commonly observed on seismic data in mud-dominated deep-water siliciclastic series. They are generally interpreted as MDAC:

- in the absence of any other convincing mechanism to produce such local anomalies
- by reference to present-day seafloor observations of seep carbonates.

MDAC formed as a result methane-rich fluids migrating through the hydraulic fractures. MDACs result from anaerobic methane oxidation and calcite precipitation.

In particular on H01 these patches are interpreted as lying very close to the seafloor, and locally are correlated to pockmarks and bubbling in the water column. In a few areas, some areas of acoustic turbidity in the nearby sediments below were also observed. In these cases, the pockmarks within these zones are considered to be active.

Information about High Impedance Reflectors were analysed and mapped on the Morphology-Shallow Geology-Geohazard Charts as part of the post survey assessment studies carried out by Fugro for this project.

5.2.5.2 Pockmarks

Pockmarks were observed on the seafloor along most of the survey corridor. They can be related both to the presence of biogenic gas and/or to dewatering phenomena during the sediment compaction. Pockmarks were not picked individually due to the large number of them, but they were identified within several areas.

Locally, where they are found in correspondence of high impedance reflectors close to the seafloor and associated with diffraction hyperbola / bubbling in the water column, these pockmarks are considered to be active, and were mapped on Morphology-Shallow Geology-Geohazard Charts. (Figure 30 and Figure 32).

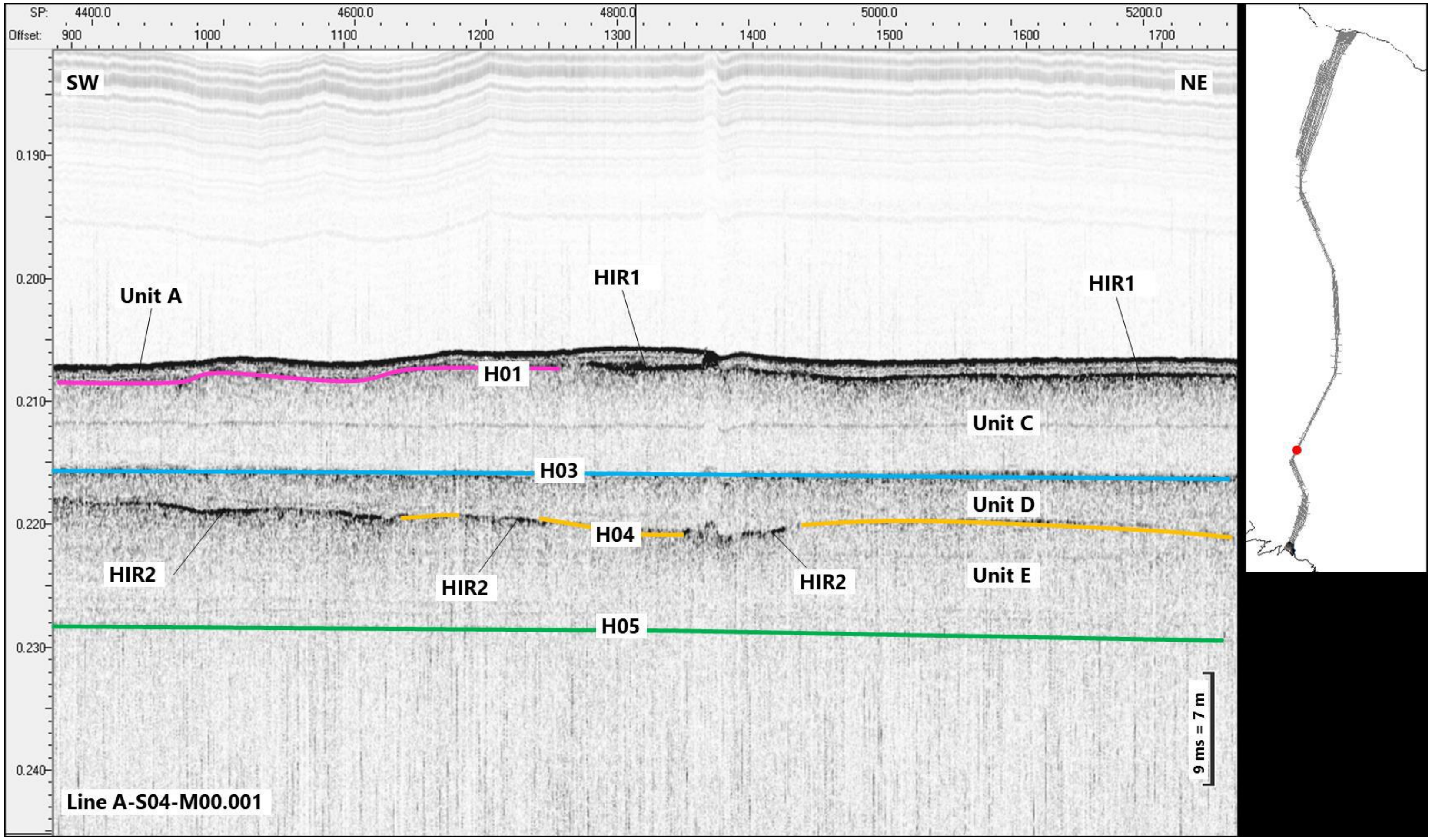


Figure 29: High Impedance Reflectors (HIR1 and HIR2) data example (SBP line A-S04-M00.001) on Sector 4

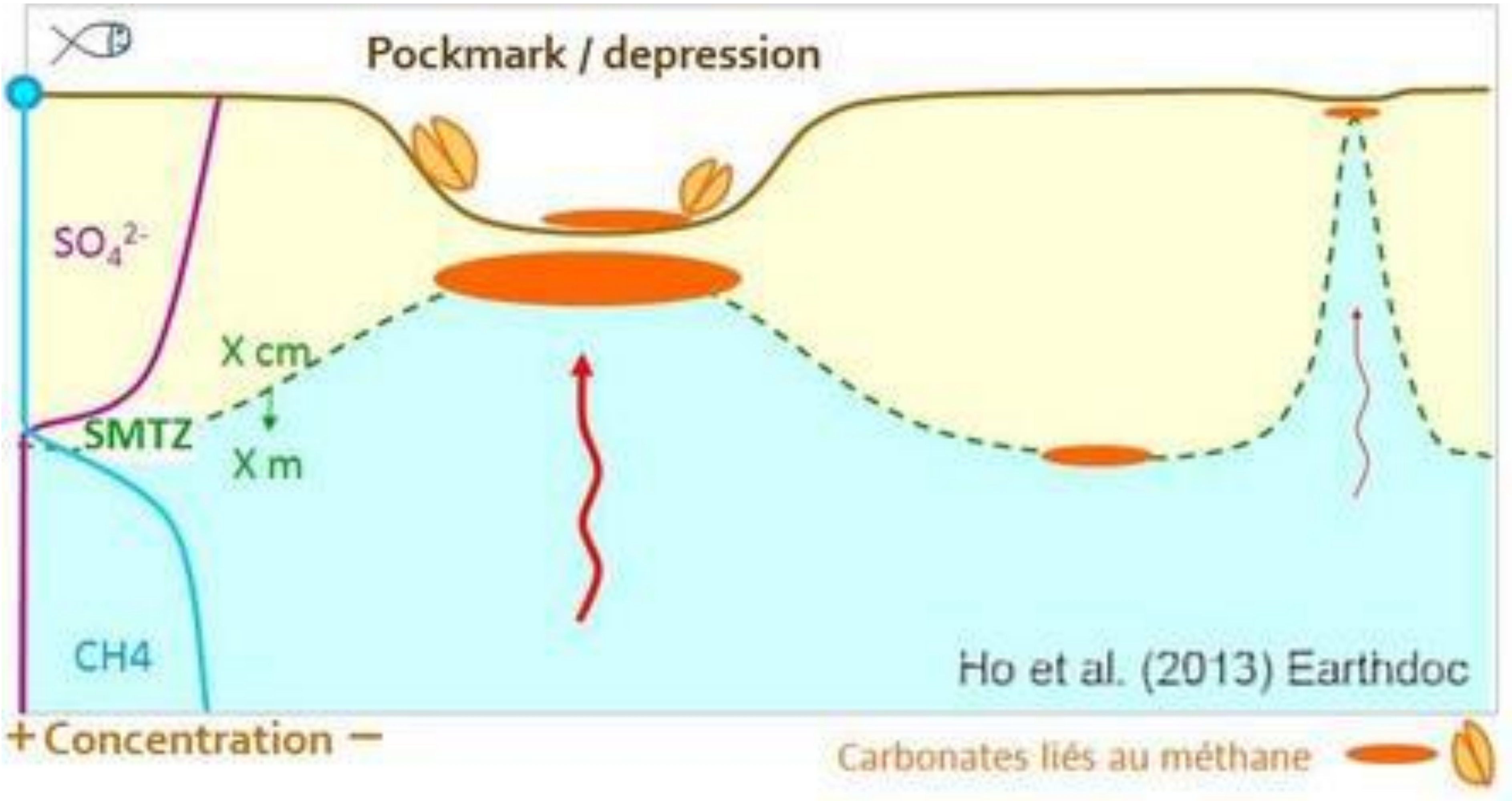


Figure 30: Conceptual model for the formation of MDA

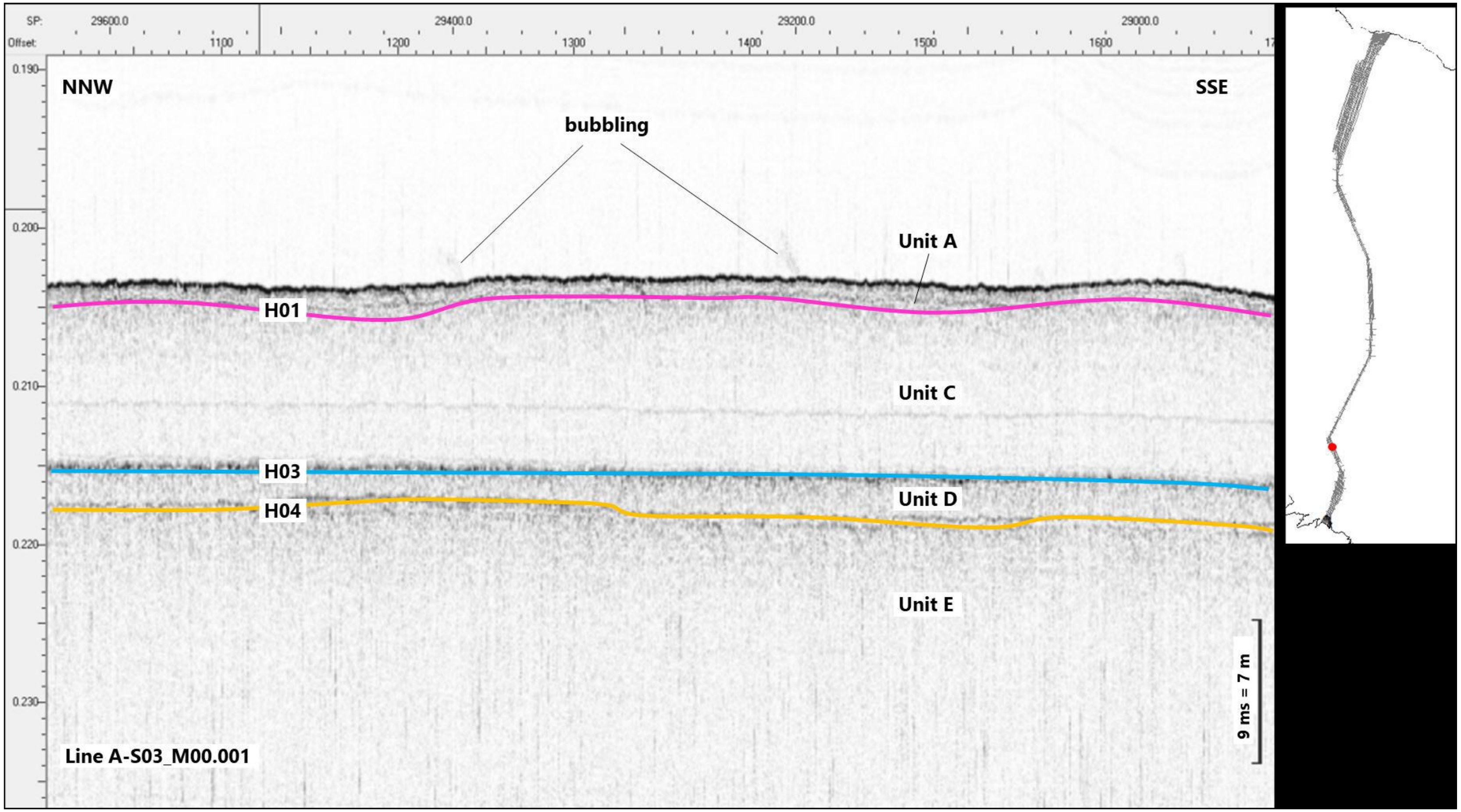


Figure 31: Bubbling in the water column data example (SBP line A-S03-M00.001) on Sector 3

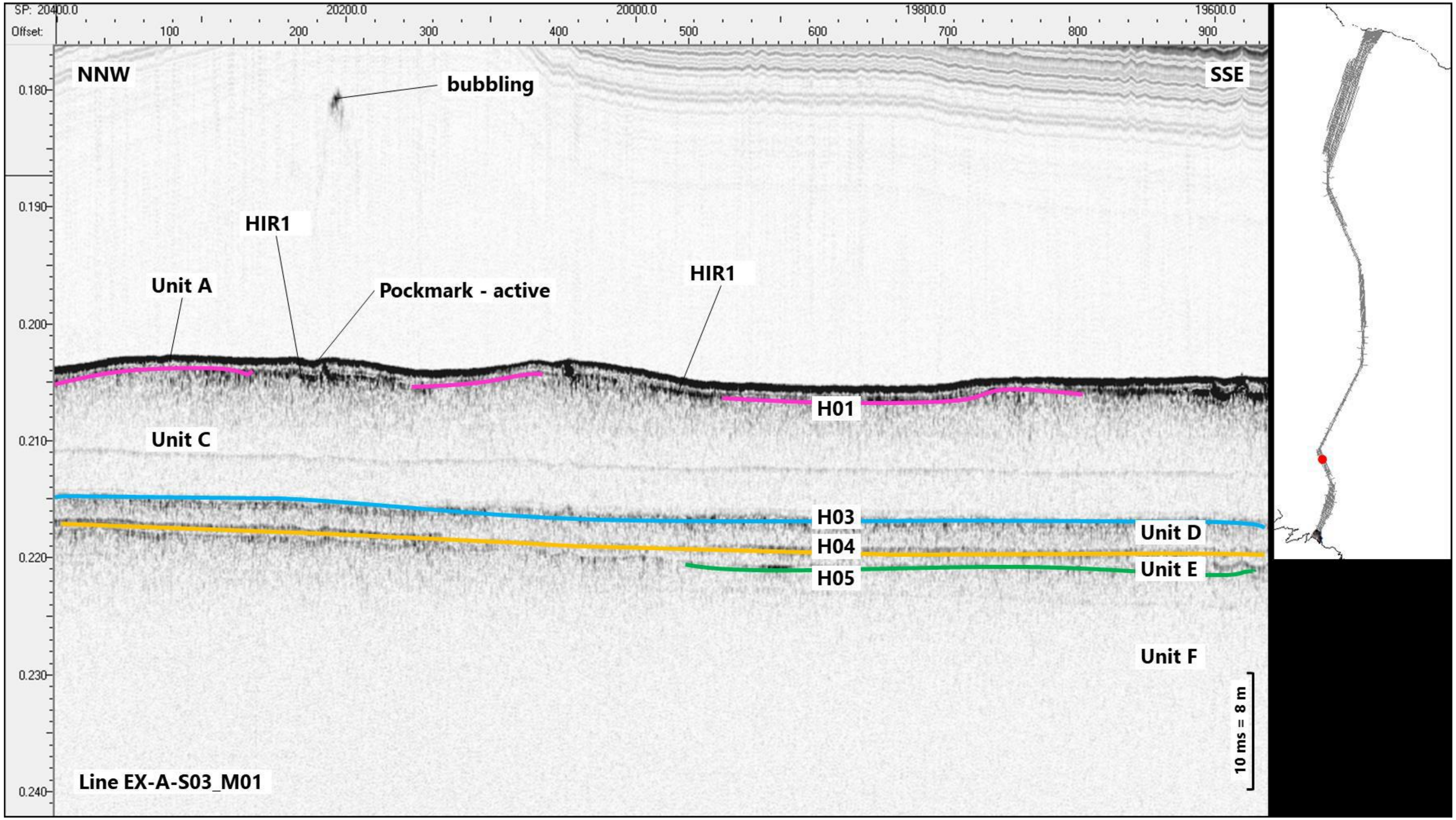


Figure 32: Possible active pockmarks data example (SBP line EX-A-S03-M01) on Sector 3

5.2.5.3 Blanking

Some restricted areas in Sector 1 and in Sector 6 show acoustic turbidity within sediments, that totally or partially masks the reflectors underneath (Figure 33). This blanking effect could be related to the presence of gas/fluids within sediments.

These features were mapped on the Morphology-Shallow Geology-Geohazard Charts.

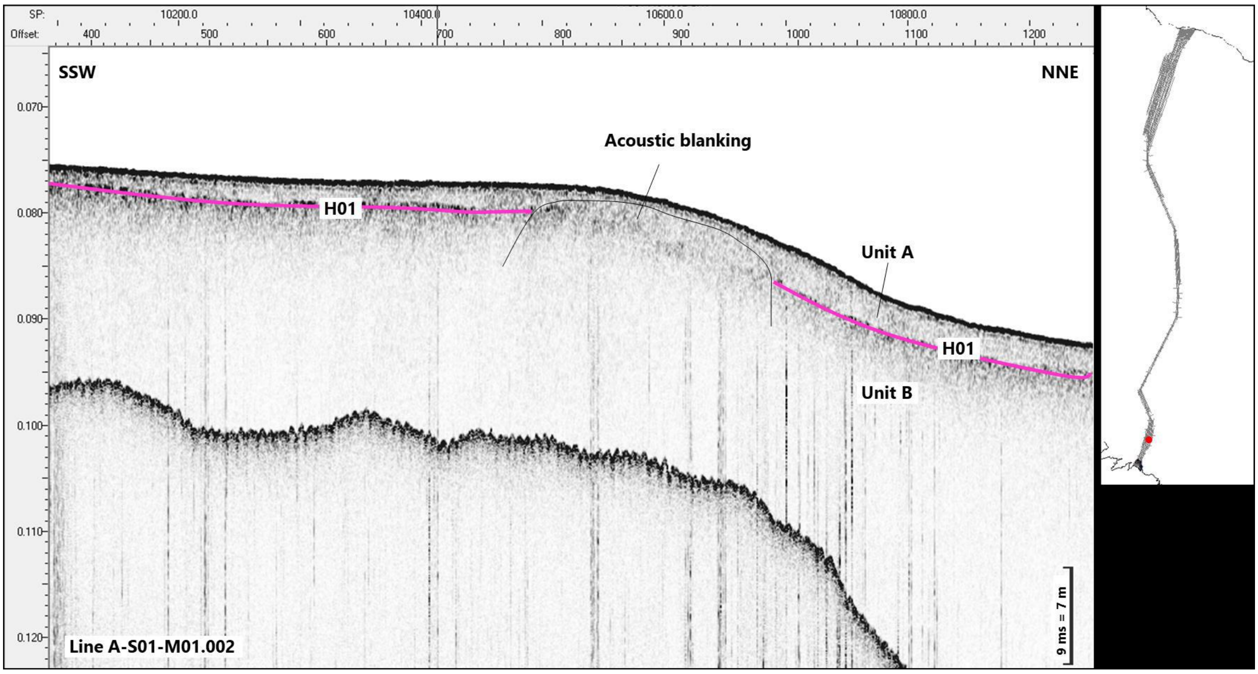


Figure 33: Acoustic blanking data example (SBP line A-S01-M01.002) on Sector 1

5.2.6 Along Route seafloor description

The following table (Table 12) describes the seafloor with all the sediments, geomorphological features and non -geological features encountered

Table 12: Interconnector 2 Malta-Italy Cable Route Position List (Note KP: kilometre point)

Proposed KPs	Sector	Morpho bathymetry feature	Depth	Main direction	Notes
0.000-0.156	1	Land	N/A	N/A	From HDD start to KP 0.156 the route runs on the land
0.156-0.773	1	Rocky outcrops and *Posidonia*	0 to -27	N/A	The seafloor is very rough, and the *Posidonia oceanica* lies probably directly on rocky outcrop (cross checked with ROV data).
0.773-1.760	1	Smooth seabed	-27 to -43	N/A	The route runs on a smooth seabed, possibly composed of medium SAND (cross checked with ROV data).
1.760-2.572	1	alternating sediments	-43 to -49	N/A	Alternation of medium SAND and coarse SAND with sparse Maerl. On the seafloor the finer sediments have a higher relief compared with the coarser ones, that lie in morphologically lower zones (cross checked with ROV data).
2.572 to -3.106	1	rippled seafloor	-49 to -48	N/A	The route runs on a rippled seabed, with coarse SAND and sparse Maerl (cross checked with ROV data).
3.220	1	cable GO-1	-48	SW-NE	In this point there should be the crossing point of the proposed route with the GO-1 cable. This cable was not observed with any of the equipment. There is the possibility that this cable was buried by time due to movement of sediment, while the seabed is composed of coarse SAND with ripples, that are a mobile feature on the seafloor. Moreover, this cable was not seen on MAG data where it crosses the route again on KP 18.160, but only by SSS data.
3.106-3.330	1	possible sub-outcrop	-48 to -49	N/A	Route going through a small relief, that was interpreted as being a possible sub-outcrop with encrusted algae on top (cross checked with ROV data in nearby areas).
3.330-3.959	1	rippled seafloor	-49 to -53	N/A	The route runs on a rippled seabed, with coarse SAND and sparse Maerl (cross checked with ROV data).

3.959-3.985	1	megaripples	-53 to -54	N/A	Megaripples area
3.985-4.712	1	rippled seafloor	-54 to -56	N/A	The route runs on a rippled seabed, with coarse SAND and sparse Maerl (cross checked with ROV data).
4.712-4.929	1	megaripples	-56 to -57	N/A	Megaripples area (checked with ROV data).
4.929-5.700	1	rippled seafloor	-57 to -58	N/A	The route runs on a rippled seabed, with coarse SAND and sparse Maerl (cross checked with ROV data).
5.700-6.780	1	maerl beds	-58 to -75	N/A	Approximately at this depth, Maerl beds became much denser. This was checked in the two ROV video that were run to the E and to the W from the proposed route.
6.780	1	scarp edge	-75	WNW-ESE	Scarp edge that leads to a lower area, and it is approximately 20 m high.
6.780-7.715	1-2	very rough seabed	-75 to -131	N/A	This area is characterized by a very rough seafloor, with dense Marl beds and blocks, and locally presence of encrusting algae. The area is also characterized by a strong presence of UXO objects. None of these was observed at a distance of less than 12 m from the proposed route.
7.715-8.031	2	smooth sandy seabed	-131 to -134	N/A	From this zone toward the N, the seabed is generally smooth. In this area fine SAND is present.
7.980	2	cable TG-PALERMO-MALTA	-134	NNW-SSE	Visible on MAG data t.
8.031-10.540	2	pockmarks area	-134 to -146	N/A	The proposed route crosses a large area with pockmarks.
10.540-20.00	2-3-4	pockmarks areas	-146 to -157	N/A	In this corridor interval a large number of pockmarks are present. These were not picked individually. A whole area was mapped. The seafloor is characterized by the presence of SILT and CLAY mixtures.
12.000	3	Archaeological target	-150	N/A	At approximately 170 m W from the proposed route, several archeological targets were observed and investigated by ROV (UXOs)
15.000	3	Archaeological target	-154	N/A	At approximately 290 m W and 140 m W from the proposed route, several archeological targets were observed and investigated by ROV (aircraft and UXOs)
18.160	4	cable GO-1	-158	NNW-SSE	Crossing point with GO-1 cable. Visible on SSS data, not detected by MAG.

19.054	4	trawl scar	-157	NNE-SSW	Crossing with a trawl scar
20.000-37.000	4-5	pockmarks areas	-157 to -153	N/A	In this corridor interval several pockmarks were observed, not picked singularly. The pockmarks areas are less dense than the interval closer to the Maltese landfall.
24.300-28.191	4	trawl scar area	-156 to -155	N-S	The route crosses an area with a large number of trawl scars, mostly N-S oriented.
27.520	4	Telegraph_Cable_Gibraltar_Malta No2	-155	NNW-SSE	Based on the DTS Telegraph_Cable_Gibraltar_Malta No2 should cross the IC2 route in this point. Not detected by any of the equipment
31.000	4	SEA-ME-WE 2 (Alexandria - BU4)	-155	WNW-ESE	Crossing point with SEA-ME-WE 2 (Alexandria - BU4). Detected by Mag data
37.000-52.500	5-6	pockmarks areas	-153 to -159	N/A	In this corridor interval several pockmarks were observed, not picked singularly. The pockmarks areas dense.
37.040-37.874	5	trawl scar area	-153	N-S	The route crosses an area with a large number of trawl scars, mostly N-S oriented.
40.560	6	Fibre_Optic_Cable_SEA_ME-WE 4 Seg 4.1	-155	WNW-ESE	The route crosses a fiber optic cable, Fibre_Optic_Cable_SEA_ME-WE 4 Seg 4.1. It was detected by Mag data.
40.952	6	trawl scar	-155	NNE-SSW	Crossing with a trawl scar
43.290	6	MENA cable (database)	-154	WNW-ESE	Crossing point with database MENA cable
43.425	6	MENA cable (as found)	-154	WNW-ESE	Crossing point with MENA cable. The cable was detected by MAG and SSS data
44.410	6	Alexandra-Sicily cable	-154	WNW-ESE	Crossing point with Alexandria-Sicily cable. The cable was not detected by any of the equipment
46.400	6	Archaeological target	-154	N/A	At approximately 130 m W from the proposed route, an archeological target was observed and investigated by ROV (aircraft)
46.890	6	France-Greece 2 – Artemis cable	-154	WNW-ESE	Based on the DTS the route should cross the France-Greece 2 – Artemis cable in this point. The cable was not detected by any of the equipment.
50.340	6	2Africa cable	-157	WNW-ESE	Crossing point with planned cable 2Africa.
52.000-60.000	6-7	pockmarks areas	-157 to -153	N/A	In this corridor interval several pockmarks were observed, not picked singularly. The pockmarks areas are not dense.

5.3 Work Package 3 - Nearshore Investigation

5.3.1 Terrestrial investigations

TERRACORE Ltd. was commissioned by InterConnect Malta Ltd. to undertake a site investigation for the construction of the second cable link inter-connector (IC2) project, Maghtab Terminal Station, Naxxar. (Figure 34).

Figure 34: Aerial Photo indicating investigated area at Maghtab Terminal Station in Naxxar. (Source: Google Earth).

5.3.2 Geological Conditions along the project area

The extract from the published Geological Map of the Maltese Islands (1993) shown in Figure 35 below indicates that the site (marked in red) is located on the Xlendi Member (*Ox*) of the Lower Coralline Limestone Formation.

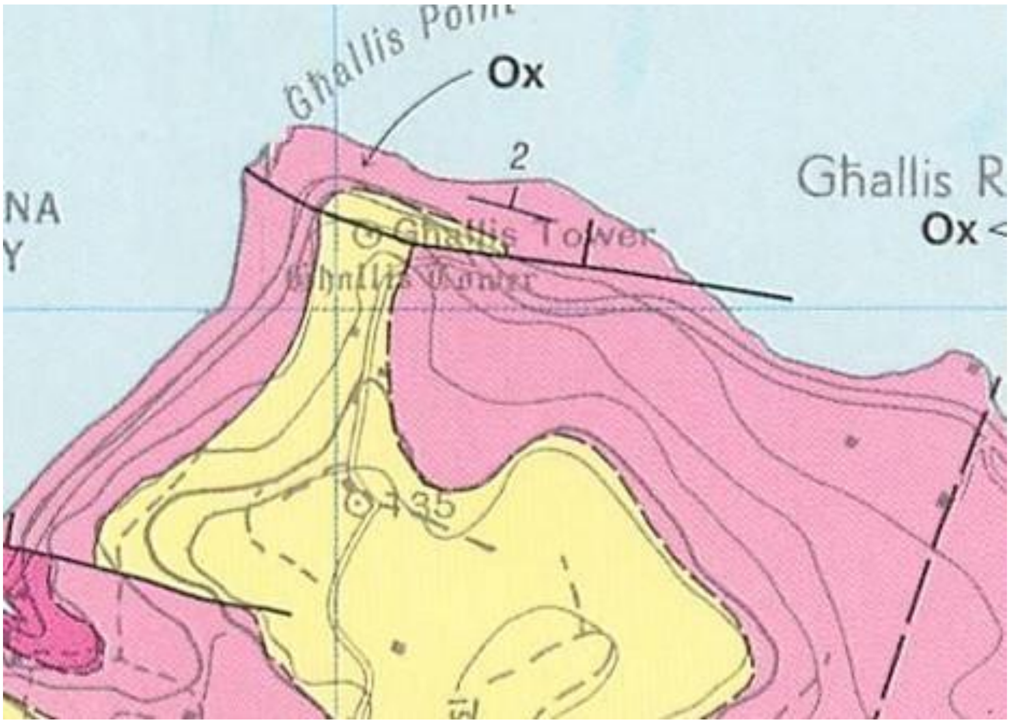


Figure 35: Geological Map of the environs of the site (OED, 1993)

Xlendi Member of Lower Coralline Limestone consists of planar to cross-stratified, coarse-grained limestones (packstones) with abundant benthic Foraminiferids and coralline algal fragments.

5.3.3 Field work

Fieldwork was undertaken on 24th of January 2023, and comprised the drilling of One (1) land-based borehole 45m deep, with core recovery, denoted as BH-1. The approximate position of this borehole is shown in Figure 36.

Figure 36: Borehole location

5.3.4 Result of the Investigation

The borehole drilling records are summarized in Table 13 below.

Table 13: Borehole drilling records.

	Date drilled	Latitude	Longitude	Elevation (m)	Top of bedrock (m)	Total depth (m)
BH-1	12 May 2022	35°57'5.85"N	14°26'21.74"E	+7.00	0.45	36.00

The main geological stratum encountered during the investigation is:

- White, light yellow, to pale grey, coarse-grained, very weak to weak Lower Coralline LIMESTONE of "Poor" to "Excellent" quality.

5.3.5 Rock Quality Designation (RQD)

Table 14 below shows the values of the quality of the rock cores recovered namely the Total Core Recovery (TCR), the Solid Core Recovery (SCR), the Rock Quality Designation (RQD) and the Fracture Index. These parameters are described in BS5930:2015.

Table 14: Quality of rock core: TCR, SCR, RQD and Fracture Index.

BH No.	Run No.	Depth (m)	TCR (%)	SCR (%)	RQD (%)	Rock Quality	Fracture Index (fractures/m)
BH-1	1	0.45 - 1.00	100	100	100	Excellent	0/m
		1.00 - 2.00	100	99	98	Excellent	1/m
		2.00 - 3.00	100	100	98	Excellent	1/m
	2	3.00 - 4.00	100	100	100	Excellent	0/m
		4.00 - 5.00	100	100	100	Excellent	1/m
		5.00 - 6.00	100	100	99	Excellent	1/m
	3	6.00 - 7.00	100	100	98	Excellent	1/m
		7.00 - 8.00	100	97	94	Excellent	1/m

BH No.	Run No.	Depth (m)	TCR (%)	SCR (%)	RQD (%)	Rock Quality	Fracture Index (fractures/m)
		8.00 - 9.00	100	100	96	Excellent	1/m
	4	9.00 - 10.00	100	97	95	Excellent	1/m
		10.00 - 11.00	100	96	90	Excellent	1/m
		11.00 - 12.00	100	98	96	Excellent	1/m
	5	12.00 - 13.00	80	75	68	Fair	1/m
		13.00 - 14.00	70	68	66	Fair	1/m
		14.00 - 15.00	50	50	46	Poor	1/m
	6	15.00 - 16.00	40	37	33	Poor	Highly fractured
		16.00 - 17.00	40	37	31	Poor	Highly fractured
		17.00 - 18.00	40	35	26	Poor	Highly fractured
	7	18.00 - 19.00	40	35	32	Poor	Highly fractured
BH-1	7	19.00 - 20.00	30	28	25	Poor	Highly fractured
		20.00 - 21.00	30	28	25	Poor	Highly fractured
	8	21.00 - 22.00	60	58	53	Fair	Highly fractured
		22.00 - 23.00	100	100	98	Excellent	1/m
		23.00 - 24.00	100	98	96	Excellent	1/m
	9	24.00 - 25.00	40	35	30	Poor	Highly fractured
		25.00 - 26.00	40	35	30	Poor	Highly fractured
		26.00 - 27.00	40	35	30	Poor	Highly fractured
	10	27.00 - 28.00	45	42	40	Poor	Highly fractured
		28.00 - 29.00	45	42	38	Poor	Highly fractured

BH No.	Run No.	Depth (m)	TCR (%)	SCR (%)	RQD (%)	Rock Quality	Fracture Index (fractures/m)
		29.00 - 30.00	40	38	35	Poor	Highly fractured
	11	30.00 - 31.00	40	40	40	Poor	Highly fractured
		31.00 - 32.00	30	30	30	Poor	Highly fractured
		32.00 - 33.00	40	40	30	Poor	Highly fractured
	12	33.00 - 34.00	30	28	25	Poor	Highly fractured
		34.00 - 35.00	50	48	46	Poor	Highly fractured
		35.00 - 36.00	50	45	39	Poor	Highly fractured

5.3.6 Laboratory Results & Interpretation

Four (4) specimens of Lower Coralline Limestone were selected from various depths along the recovered rock core, for Unconfined Compressive Strength (UCS) testing. The rock specimens were tested according to the ISRM suggested method. The laboratory results are summarised in Table 15 below, and the test certificates are located in Appendix 1.

Table 15: Unconfined compressive strength (UCS) of the limestone specimens.

BH No.	Run No.	Specimen No.	Depth (m)	Bulk Density (kg/m^3)	Dry Density (kg/m^3)	Water Content (%)	UCS (MPa)	Average UCS (MPa)
BH-1	3	1	8.30	2237	2049	8.4	16.2	**8.8**
	8	2	23.40	2197	1910	13.1	6.2	
	10	3	29.25	2133	1851	13.3	9.4	
	11	4	30.20	2051	1693	17.4	3.5	

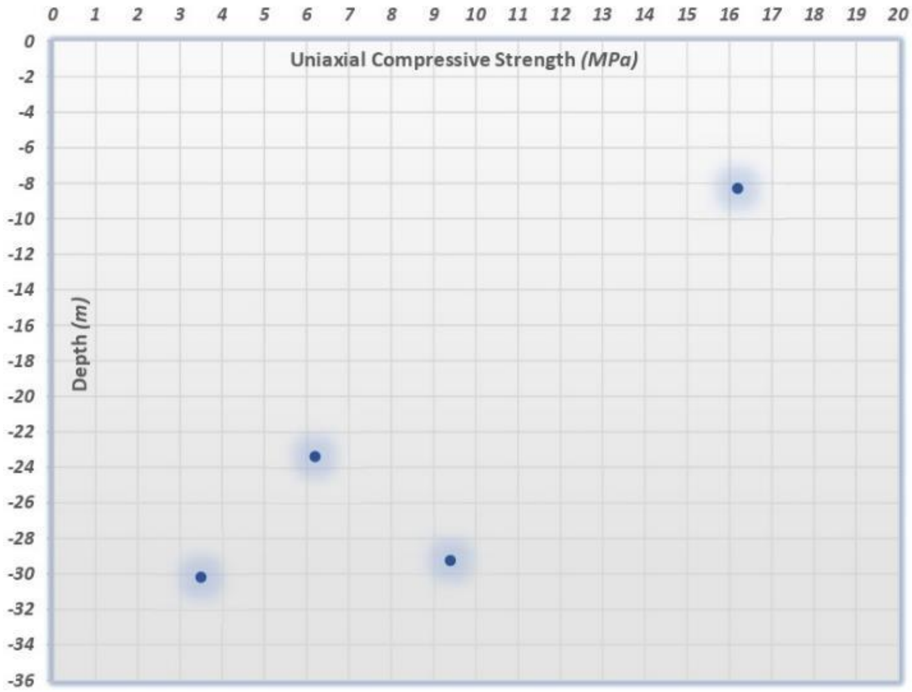


Figure 37: Scatter diagram of unconfined compression test results per depth.

The UCS of the tested Lower Coralline Limestone ranged from **3.5MPa** to **16.2MPa**.

To note that the values of the UCS refer to the strength of intact rock, and it is not the strength of the rock mass. The UCS values exclude any weaker or fractured rock that could not be tested. Based on the description of the rock strength given in BS EN ISO 14689-1:2003 and BS5930:2015, the strength of the tested specimens of the recovered Lower Coralline Limestone are classified as being **"very weak"** to **"weak"**.

5.3.7 Conclusions

1. The site investigation carried out for the construction of the second cable link inter-connector project, Maghtab Terminal Station, Naxxar comprised the drilling of One (1) land-based borehole with full recovery.

2. The recovered rock core consists of "Poor" to "Excellent" quality, very weak to weak, Lower Coralline Limestone.
   - Rock Quality, ***RQD=60.4%*** *(Fair, taken as an average)*
   - Geological Strength Index, ***GSI=75*** *(Blocky)*
   - Rock Mass Rating, ***RMR=55*** *(Class III-Fair Rock)*
3. No voids were detected during drilling.
4. Four (4) specimens from the recovered Lower Coralline Limestone samples were tested for unconfined compressive strength (UCS). The UCS of the tested Limestone ranged from **3.5MPa** to **16.2MPa**.

5.3.8 Nearshore Geological Investigation

TERRACORE Ltd. was commissioned by **AquaBio Tech Group** to undertake a nearshore site investigation in connection with the laying of the second cable link Interconnector Project, Il-Maghtab, Naxxar. (Figure 38**).** This consisted of the drilling of 3 holes on offshore locations by continuous rock core sampling.

The aim of the investigation was to identify the existing seabed conditions, top of bedrock and the presence of clay beds, caverns and voids as well as the quality of rock/soil beneath the site.

Figure 38: Google image showing location of the site at Ghallis

5.3.8.1 Standards and Guidance

The site investigation was conducted in full accordance with *BS 5930:2015 "Code of practice for geological site investigations"*, *BS EN 1997:2004 "Geotechnical Design – Part 1: General Rules"* and *BS EN 1997-2:2007 "Geotechnical Design - Part 2: Ground Investigation and Testing"*.

Uniaxial compressive strength tests on rock samples were performed according to the *International Society for Rock Mechanics (ISRM) suggested methods* and *Annex W of EN 1997-2:2007*.

5.3.8.2 Location of the site

The investigated site is located at il-Ghallis Coastline l/o Il-Maghtab, Naxxar and is indicated in Figure 39**.**

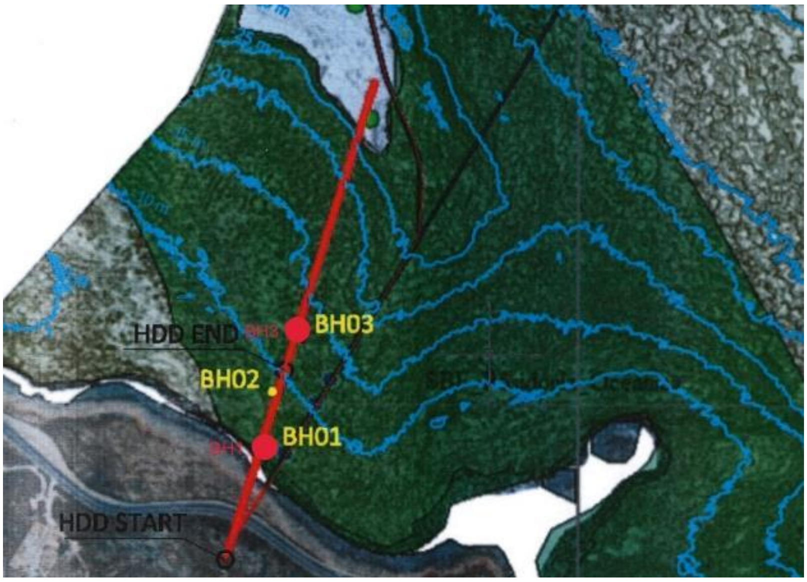


Figure 39: Google image showing the location of the boreholes at il-Ghallis

5.3.8.3 Geological Conditions along the project area

The extract from the published Geological Map of the Maltese Islands (1993) shown in Figure 40 below indicates that the site (marked in red) is located on the Xlendi Member (*Ox*) of the Lower Coralline Limestone Formation.

<u>Xlendi Member of Lower Coralline Limestone</u> consists of planar to cross-stratified, coarse-grained limestones (packstones) with abundant coralline algal fragments.

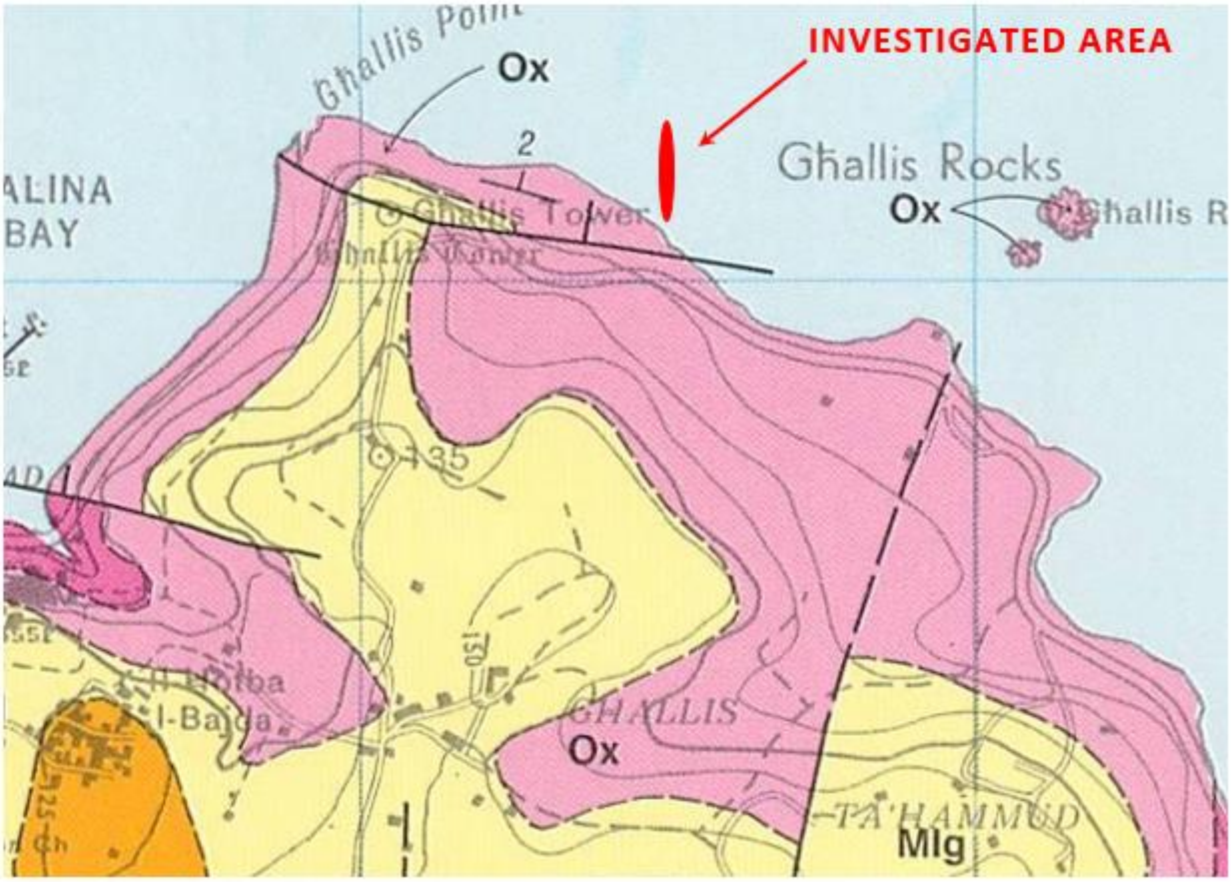


Figure 40: Geological map extract showing the geology of the area (Source: Geological Map of the Maltese Islands, 1993).

5.3.8.4 Site Works - In situ investigation

Fieldwork was undertaken on 29th and 30th of December 2022, and comprised the drilling of Two (2) sea-based boreholes with core recovery, denoted as BH-1 and BH-3. The approximate position of these boreholes is shown in Figure 39.

The borehole drilling records are shown in **Appendix 1** and summarized in Table 16 below.

Table 16: Borehole drilling records

	Date drilled	*Easting*	*Northing*	*Elevation (m)*	*Top of bedrock (m)*	*Total depth (m)*
BH-1	30 Dec. 2022	449465.54	3978924.64	±0.00 MSL	-5.70	-50.70
BH-3	29 Dec. 2022	449519.30	3979112.75	±0.00 MSL	-12.20	-57.20

5.3.8.5 Rock Mass Characterization

The main geological stratum encountered during the investigation is:

- white to pale grey, coarse-grained, blocky, very weak to medium strong Lower Coralline LIMESTONE of "Poor" to "Excellent" quality.

Photographs of the samples recovered are shown in Appendix 1. The borehole logs are located in **Appendix 1.**

Table 17 below summarize the **Rock Core Descriptors** and **Supplemental Descriptors**.

Table 17: Rock Mass Characterization

Rock Mass Characterization	
Rock Core Descriptors	
Unit designation:	*Lower Coralline Limestone.*
Rock type:	*Limestone.*
Colour:	*White to pale grey.*
Degree of weathering:	*Unweathered (UW) to Slightly weathered (SW). Slight discoloration on surface, slight alteration along discontinuities, less than 10 percent of the rock volume altered.*
Hardness:	*Very Soft to medium strong.*
Texture:	*Coarse grained.*
Structure:	*Blocky.*
Degree of Fracturing (Jointing):	*Slightly to Moderately fractured. Locally Highly fractured.*
Condition of discontinuities:	*Unweathered Joints to slightly weathered.*
Alteration:	*No rock alteration was encountered.*
Supplemental Descriptors	

Orientation of discontinuities:	*Oblique joints (20 to 45 degrees).*
Discontinuities thickness:	*Tight to very tight.*
Discontinuities infilling:	*No infilling or few oxides/clayey material.*
Roughness of discontinuities:	*Slightly Rough (JCR=4-6) to Rough (JCR=6-8).*
Cavities:	*No cavities were detected during drilling.*

5.3.8.6 Rock Quality Designation (RQD)

The quality of the rock cores recovered namely the Total Core Recovery (TCR), the Solid Core Recovery (SCR), the Rock Quality Designation (RQD) and the Fracture Index are listed in Table 18 and Table 19. These parameters are described in Figure 43 and Figure 44 according to BS5930:2015.

Table 18: Quality of rock core: TCR, SCR, RQD and Fracture Index. (BH-1)

BH No.	Run No.	Depth (m)	TCR (%)	SCR (%)	RQD (%)	Rock Quality	Fracture Index (fractures/m)
BH-1	1	-5.70 to -6.70	90	88	83	Good	3/m
		-6.70 to -7.70	100	98	92	Excellent	3/m
		-7.70 to -8.70	50	47	42	Poor	Highly Fractured
	2	-8.70 to -9.70	100	97	66	Fair	2/m
		-9.70 to -10.70	100	98	75	Good	2/m
		-10.70 to -11.70	100	96	54	Fair	Moderately fractured
	3	-11.70 to -12.70	100	98	92	Excellent	3/m
		-12.70 to -13.70	80	80	77	Good	1/m
		-13.70 to -14.70	50	50	50	Fair	Highly fractured
	4	-14.70 to -15.70	100	100	98	Excellent	1/m
		-15.70 to -16.70	100	98	95	Excellent	2/m
		-16.70 to -17.70	70	70	70	Fair	1/m

BH No.	Run No.	Depth (m)	TCR (%)	SCR (%)	RQD (%)	Rock Quality	Fracture Index (fractures/m)
	5	-17.70 to -18.70	85	83	53	Fair	Moderately fractured
		-18.70 to -19.70	80	76	52	Fair	Moderately fractured
		-19.70 to -20.70	60	60	53	Fair	Highly fractured
	6	-20.70 to -21.70	90	86	74	Fair	3/m
		-21.70 to -22.70	90	87	81	Good	3/m
		-22.70 to -23.70	80	77	71	Fair	Moderately fractured
	7	-23.70 to -24.70	60	56	38	Poor	Highly fractured
		-24.70 to -25.70	50	46	35	Poor	Highly fractured
		-25.70 to -26.70	50	43	31	Poor	Highly fractured
BH-1	8	-26.70 to -27.70	70	68	57	Fair	2/m
		-27.70 to -28.70	60	59	55	Fair	2/m
		-28.70 to -29.70	70	68	51	Fair	Highly fractured
	9	-29.70 to -30.70	60	56	41	Poor	Moderately fractured
		-30.70 to -31.70	70	64	59	Fair	Moderately fractured
		-31.70 to -32.70	60	53	48	Poor	Moderately fractured
	10	-32.70 to -33.70	100	98	95	Excellent	1/m
		-33.70 to -34.70	80	75	70	Fair	2/m
		-34.70 to -35.70	80	74	67	Fair	Moderately fractured
	11	-35.70 to -36.70	100	100	100	Excellent	1/m
		-36.70 to -37.70	100	98	96	Excellent	1/m
		-37.70 to -38.70	100	97	92	Excellent	2/m
	12	-38.70 to -39.70	100	97	91	Excellent	2/m
		-39.70 to -40.70	100	98	93	Excellent	1/m
		-40.70 to -41.70	90	87	81	Good	2/m
	13	-41.70 to -42.70	90	86	71	Fair	2/m
		-42.70 to -43.70	100	97	91	Excellent	2/m

BH No.	Run No.	Depth (m)	TCR (%)	SCR (%)	RQD (%)	Rock Quality	Fracture Index (fractures/m)
		-43.70 to -44.70	70	68	65	Fair	2/m
	14	-44.70 to -45.70	90	86	81	Good	2/m
		-45.70 to -46.70	100	98	91	Excellent	2/m
		-46.70 to -47.70	90	88	85	Good	1/m
	15	-47.70 to -48.70	90	87	80	Good	2/m
		-48.70 to -49.70	80	78	76	Good	2/m
		-49.70 to -50.70	50	49	45	Fair	Highly fractured

Table 19: Quality of rock core: TCR, SCR, RQD and Fracture Index. (BH-3)

BH No.	Run No.	Depth (m)	TCR (%)	SCR (%)	RQD (%)	Rock Quality	Fracture Index (fractures/m)
BH-3	1	-12.20 to -13.20	100	100	72	Fair	Moderately fractured
		-13.20 to -14.20	100	98	89	Good	2/m
		-14.20 to -15.20	100	95	80	Good	Moderately fractured
	2	-15.20 to -16.20	100	95	74	Fair	Moderately fractured
		-16.20 to -17.20	100	100	97	Excellent	1/m
		-17.20 to -18.20	100	96	89	Good	2/m
	3	-18.20 to -19.20	70	65	58	Fair	Highly fractured
		-19.20 to -20.20	60	53	46	Poor	Highly fractured
		-20.20 to -21.20	50	48	42	Poor	Highly fractured
	4	-21.20 to -22.20	80	77	65	Fair	1/m
		-22.20 to -23.20	80	74	61	Fair	2/m
		-23.20 to -24.20	70	68	59	Fair	Highly fractured
	5	-24.20 to -25.20	90	90	89	Good	1/m
		-25.20 to -26.20	90	90	87	Good	1/m

BH No.	Run No.	Depth (m)	TCR (%)	SCR (%)	RQD (%)	Rock Quality	Fracture Index (fractures/m)
		-26.20 to -27.20	50	50	43	Poor	Highly fractured
	6	-27.20 to -28.20	90	85	76	Good	2/m
		-28.20 to -29.20	90	86	77	Good	1/m
		-29.20 to -30.20	70	70	65	Fair	Highly fractured
	7	-30.20 to -31.20	70	65	61	Fair	1/m
		-31.20 to -32.20	70	63	59	Fair	2/m
		-32.20 to -33.20	60	56	51	Fair	Highly fractured
	8	-33.20 to -34.20	100	100	100	Excellent	2/m
		-34.20 to -35.20	90	89	85	Good	2/m
		-35.20 to -36.20	80	78	75	Good	1/m
BH-3	1	-36.20 to -37.20	90	85	77	Good	1/m
		-37.20 to -38.20	90	84	78	Good	1/m
		-38.20 to -39.20	60	68	67	Fair	Highly fractured
	2	-39.20 to -40.20	90	90	87	Good	1/m
		-40.20 to -41.20	85	82	78	Good	1/m
		-41.20 to -42.20	75	75	71	Good	Moderately fractured
	3	-42.20 to -43.20	60	57	50	Fair	2/m
		-43.20 to -44.20	55	54	49	Poor	1/m
		-44.20 to -45.20	50	48	45	Poor	Highly fractured
	4	-45.20 to -46.20	90	89	85	Good	1/m
		-46.20 to -47.20	90	85	79	Good	2/m
		-47.20 to -48.20	60	60	51	Fair	Highly fractured
	5	-48.20 to -49.20	100	98	91	Excellent	1/m
		-49.20 to -50.20	100	100	100	Excellent	1/m

BH No.	Run No.	Depth (m)	TCR (%)	SCR (%)	RQD (%)	Rock Quality	Fracture Index (fractures/m)
		-50.20 to -51.20	100	97	95	Excellent	1/m
	6	-51.20 to -52.20	100	96	91	Excellent	1/m
		-52.20 to -53.20	100	97	94	Excellent	2/m
		-53.20 to -54.20	100	100	99	Excellent	1/m
	7	-54.20 to -55.20	100	99	94	Excellent	1/m
		-55.20 to -56.20	100	100	97	Excellent	1/m
		-56.20 to -57.20	50	50	50	Fair	Highly fractured

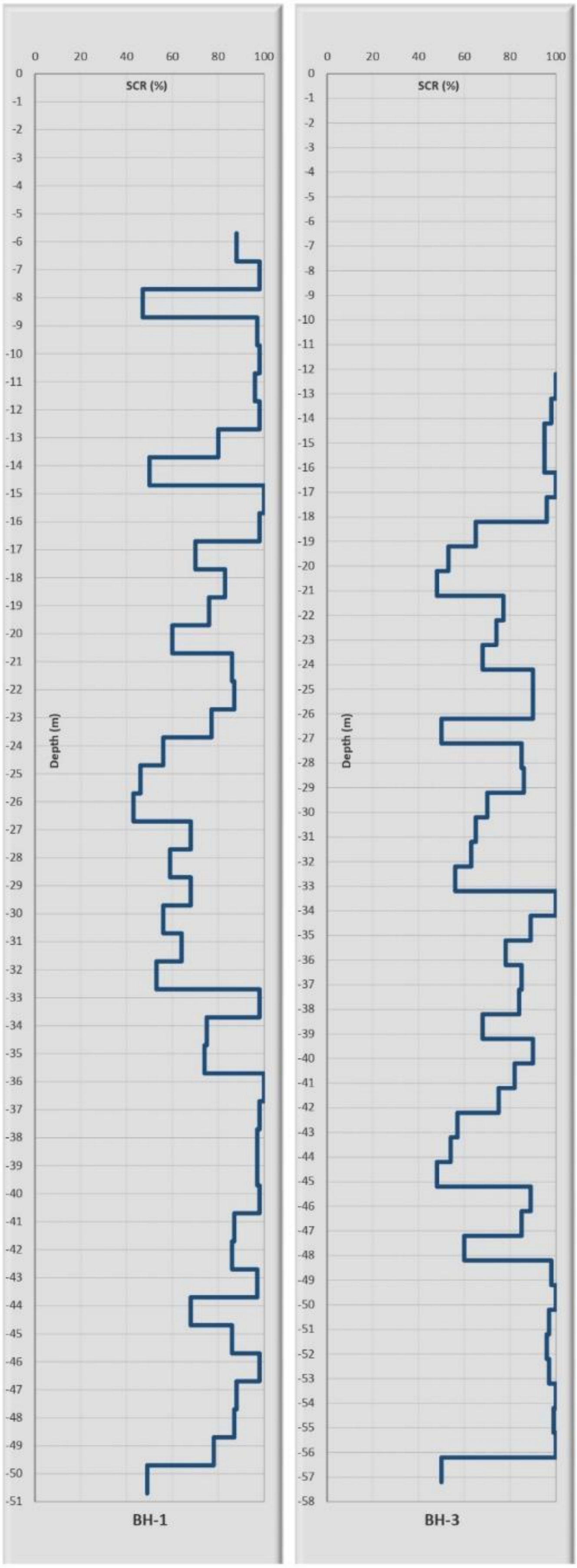


Figure 41: Plot of SCR with depth

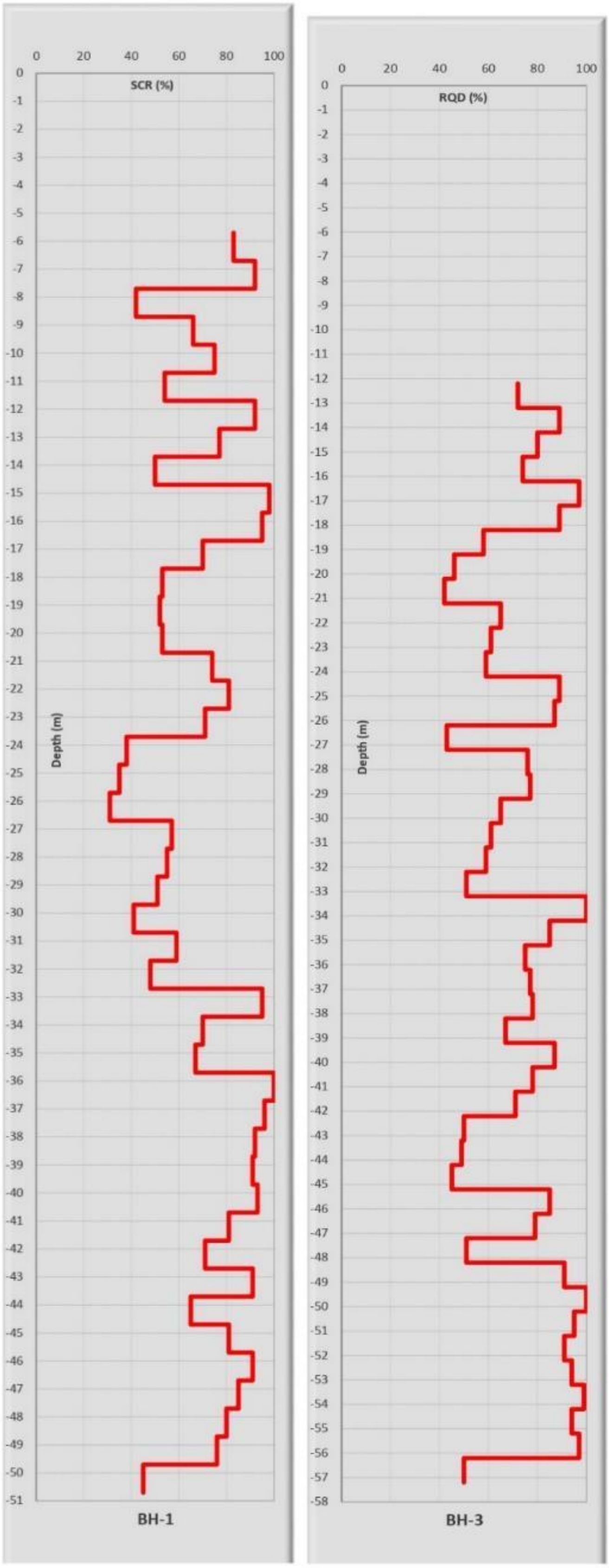


Figure 42: Plot of solid core recovery (SCR) and RQD with depth

Terms for classification of discontinuity state (see Figure 10)

TCR (%)	Length of core recovered (solid and non-intact) expressed as a ratio of the length of core run.
SCR (%)	Length of solid core recovered expressed as a ratio of the length of core run. Solid core has a full diameter, uninterrupted by natural discontinuities, but not necessarily a full circumference and is commonly measured along the core axis or other scan line.
RQD (%)	Length of solid core each pieces longer than 100 mm expressed as a ratio of the length of core run.
Fracture index	Count of the number or spacing of fractures over an arbitrary length of core of similar intensity of fracturing recorded as minimum/mode/maximum. Commonly reported as Fracture Spacing (If, mm) or as Fracture Index (FI, number of fractures per metre). Where core is non-intact in the ground, the abbreviation NI may be used.

NOTE The total core recovery (TCR) records the proportion of core recovered and is read with the description, solid core recovery (SCR) and rock quality designation (RQD). The TCR of itself gives little information on the character of the core or the rock from which it was recovered. This measurement is required to ensure that all depth related records such as boundaries, markers and samples are correct.

Figure 43: Terms for classification of discontinuity state (Table 31 of BS5930:2015).

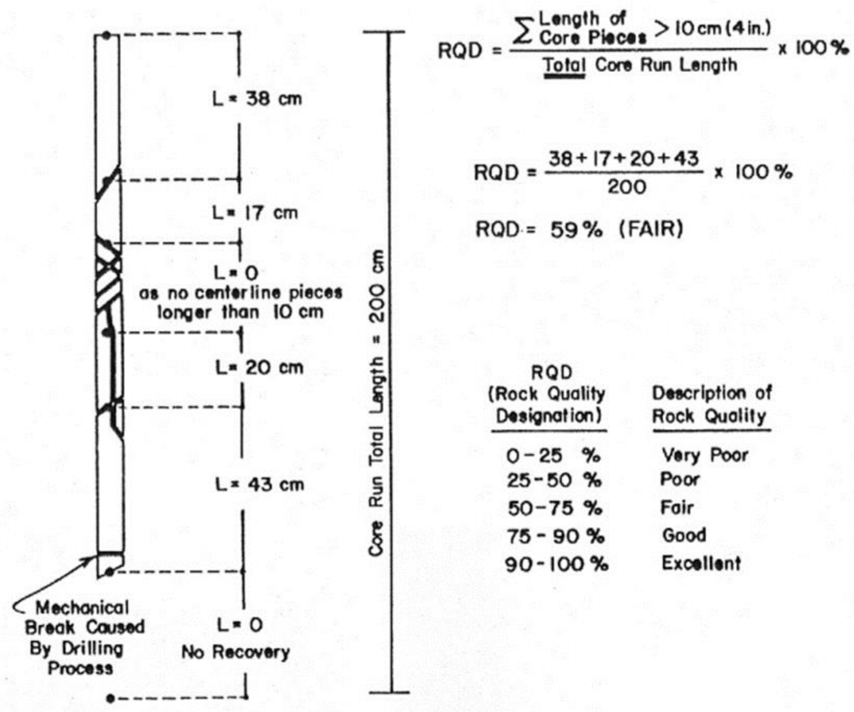


Figure 44: RQD Classification Index (Deere and Deere, 1988).

5.3.8.7 Geomechanics Classification – Rock Mass Rating (RMR)

The Geomechanics Classification, or Rock Mass Rating (RMR) system, proposed by Bieniawski (1973), was initially developed for tunnels. In recent years, it has been applied to the preliminary design of rock slopes and foundations as well as for estimating the in-situ modulus of deformation and rock mass strength. The RMR uses six parameters that are readily determined in the field:

- Uniaxial compressive strength of the intact rock.
- Rock Quality Designation (RQD).
- Spacing of discontinuities.
- Condition of discontinuities.
- Ground water conditions.
- Orientation of discontinuities.

The classes provided in the Table 20 below are the final output. This RMR class provides the basis for strength assessment and support requirements.

Table 20: Rock mass classes (Bieniawski, 1989).

RMR class no.	***Description***	***Rating***
I	Very good rock	100 - 81
II	Good rock	80 - 61
III	Fair rock	60 - 41
IV	Poor rock	40 - 21
V	Very poor rock	<20

Table 21: Rock Mass Rating System (after Bieniawski, 1989).

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

	Parameter		Range of values						
1	Strength of intact rock material	Point-load strength index	>10 MPa	4 - 10 MPa	2 - 4 MPa	1 - 2 MPa	For this low range - uniaxial compressive test is preferred		
		Uniaxial comp. strength	>250 MPa	100 - 250 MPa	50 - 100 MPa	25 - 50 MPa	5 - 25 MPa	1 - 5 MPa	< 1 MPa
	Rating		15	12	7	4	2	1	0
2	Drill core Quality *RQD*		90% - 100%	75% - 90%	50% - 75%	25% - 50%	< 25%		
	Rating		20	17	13	8	3		
3	Spacing of		> 2 m	0.6 - 2 . m	200 - 600 mm	60 - 200 mm	< 60 mm		
	Rating		20	15	10	8	5		
4	Condition of discontinuities (See E)		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Highly weathered walls	Slickensided surfaces or Gouge < 5 mm thick or Separation 1-5 mm Continuous	Soft gouge >5 mm thick or Separation > 5 mm Continuous		
	Rating		30	25	20	10	0		
5	Groundwater	Inflow per 10 m tunnel length (l/m)	None	< 10	10 - 25	25 - 125	> 125		
		(Joint water press)/ (Major principal σ)	0	< 0.1	0.1, - 0.2	0.2 - 0.5	> 0.5		
		General conditions	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating		15	10	7	4	0		

B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)

Strike and dip orientations		Very favourable	Favourable	Fair	Unfavourable	Very Unfavourable
Ratings	Tunnels & mines	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

Rating	100 ← 81	80 ← 61	60 ← 41	40 ← 21	< 21
Class number	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

D. MEANING OF ROCK CLASSES

Class number	I	II	III	IV	V
Average stand-up time	20 yrs for 15 m span	1 year for 10 m span	1 week for 5 m span	10 hrs for 2.5 m span	30 min for 1 m span
Cohesion of rock mass (kPa)	> 400	300 - 400	200 - 300	100 - 200	< 100
Friction angle of rock mass (deg)	> 45	35 - 45	25 - 35	15 - 25	< 15

E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions

Discontinuity length (persistence) Rating	< 1 m 6	1 - 3 m 4	3 - 10 m 2	10 - 20 m 1	> 20 m 0
Separation (aperture) Rating	None 6	< 0.1 mm 5	0.1 - 1.0 mm 4	1 - 5 mm 1	> 5 mm 0
Roughness Rating	Very rough 6	Rough 5	Slightly rough 3	Smooth 1	Slickensided 0
Infilling (gouge) Rating	None 6	Hard filling < 5 mm 4	Hard filling > 5 mm 2	Soft filling < 5 mm 2	Soft filling > 5 mm 0
Weathering Ratings	Unweathered 6	Slightly weathered 5	Moderately weathered 3	Highly weathered 1	Decomposed 0

F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING**

Strike perpendicular to tunnel axis		Strike parallel to tunnel axis	
Drive with dip - Dip 45 - 90°	Drive with dip - Dip 20 - 45°	Dip 45 - 90°	Dip 20 - 45°
Very favourable	Favourable	Very unfavourable	Fair
Drive against dip - Dip 45-90°	Drive against dip - Dip 20-45°	Dip 0-20 - Irrespective of strike°	
Fair	Unfavourable	Fair	

* Some conditions are mutually exclusive . For example, if infilling is present, the roughness of the surface will be overshadowed by the influence of the gouge. In such cases use A.4 directly.
** Modified after Wickham et al (1972).

The RMR value for the project under consideration is determined as follows (**Table 24**):

Table 22: RMR rating.

Item	*Value*	*Rating*
Uniaxial compressive strength of the intact rock	11.4MPa	2
Rock Quality Designation (RQD)	72%	13
Spacing of discontinuities	60mm-200mm	8
Condition of discontinuities		25
Ground water conditions	Submerged	0
Orientation of discontinuities		0
	Total Rating	**48** *(Class III)* *Fair Rock*

5.3.8.8 Laboratory Results & Interpretation

Twenty-six (26) specimens of Lower Coralline Limestone were selected from various depths along the recovered rock cores, for Unconfined Compressive Strength (UCS) testing and Twenty-eight (28) specimens for Determination of Point Load Strength. The rock specimens were tested according to the ISRM suggested method. The laboratory results are summarised in Table 23 and Figure 45 below, and the test certificates are located in Appendix 1.

The following three (3) samples were destroyed during the test preparation and therefore were not tested for UCS:

i. Sample No. 11: BH-3 at -46.85m
ii. Sample No. 12: BH-3 at -47.30m
iii. Sample No. 23: BH-1 at -41.20m

Table 23: Unconfined compressive strength (UCS) of the limestone specimens.

BH No.	Run No.	Specimen No.	Depth (m)	Bulk Density (kg/m³)	Dry Density (kg/m³)	Water Content (%)	UCS (MPa)	Average UCS (MPa)
BH-1	1	16	-6.30	2375	2288	3.7	17.9	**12.0**
	4	17	-15.55	1945	1461	24.9	1.6	
	4	18	-17.20	2087	1684	19.3	2.8	
	10	19	-33.20	2195	1898	13.5	12.4	
	11	20	-35.90	2096	1819	13.2	8.1	
	11	21	-38.55	2181	1867	14.4	9.4	
	12	22	-39.30	2303	2082	9.6	14.3	
	13	24	-44.30	2385	2223	6.8	23.1	
	14	25	-46.20	2327	2146	7.8	15.7	
	14	26	-47.40	2327	2148	7.7	14.3	
BH-3	1	1	-13.00	2338	2183	6.6	11.4	**11.0**
	2	2	-16.70	2162	1850	14.5	9.3	
	4	3	-23.10	2097	1741	17.0	5.0	
	5	4	-24.90	2179	1850	15.1	26.9	
	5	5	-25.90	2248	1976	12.1	5.9	
	6	6	-28.40	2189	1868	14.7	4.7	
	7	7	-30.95	2072	1706	17.7	2.9	
	8	8	-33.70	2145	1828	14.8	7.1	
	9	9	-38.30	2212	2001	9.5	7.1	
	10	10	-39.40	2298	2056	10.5	11.5	
	13	13	-49.35	2396	2251	6.1	28.6	
	14	14	-53.50	2109	1746	17.2	7.9	
	15	15	-55.40	2271	2093	7.8	15.2	

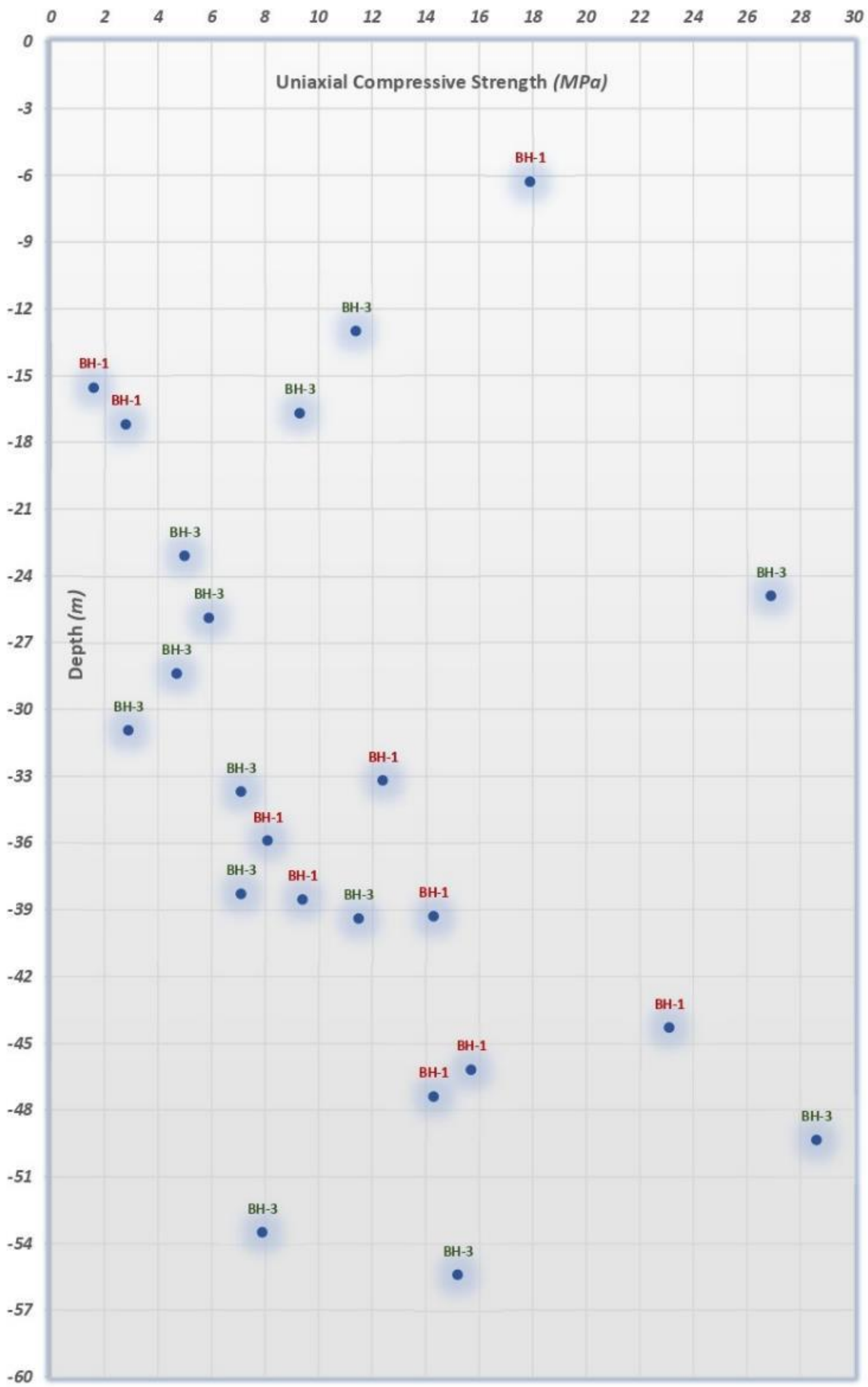


Figure 45: Scatter diagram of unconfined compression test results per depth.

The UCS of the tested Lower Coralline Limestone ranged from **1.6MPa** to **28.6MPa**.

To note that the values of the UCS refer to the strength of intact rock, and it is not the strength of the rock mass. The UCS values exclude any weaker or fractured rock that could not be tested. Based on the description of the rock strength given in BS EN ISO 14689-1:2003 and BS5930:2015 (Figure 46 below), the strength of the tested specimens of the recovered Lower Coralline Limestone are classified as being **"very weak"** to **"medium strong"**.

Terms for description of rock strength

Term for use in field or based on measurement	Definition for field use	Definition on basis of Unconfined Compressive Strength measurements MPa
Extremely weak	Can be indented by thumbnail. Gravel sized lumps crush between finger and thumb.	0.6 – 1.0
Very weak	Crumbles under firm blows with point of geological hammer. Can be peeled by a pocket knife.	1 – 5
Weak	Can be peeled by a pocket knife with difficulty. Shallow indentations made by firm blow with the point of geological hammer.	5 – 25
Medium strong	Cannot be scraped with pocket knife. Can be fractured with a single firm blow of geological hammer.	25 – 50
Strong	Requires more than one blow of geological hammer to fracture.	50 – 100
Very strong	Requires many blows of geological hammer to fracture.	100 – 250
Extremely strong	Can only be chipped with geological hammer.	>250

NOTE Based on BS EN ISO 14689-1:2003 4.2.7, Table 5.

Figure 46: Terms for description of rock strength (Table 25 of BS5930:2015).

Physical & Mechanical properties of the recovered lower Coralline Limestone

The following table (Table 24) presents the range of values and the statistical processing of the physical & mechanical properties of the recovered Lower Coralline Limestone (Table 25).

Table 24: Physical & Mechanical Properties of the recovered Limestone.

Physical & Mechanical Properties	Value Range		Number of Values	Mean Values	Standard Deviation
	from	to			
Bulk Density, ρ [Mg/m^3]	1.95	2.40	23	2.21	0.12
Dry Density, ρ_d [Mg/m^3]	1.46	2.29	23	1.95	0.21
Water content [%]	3.7	24.9	23	12.4	5.09
Unconfined Compression Strength [MPa]	1.6	28.6	23	11.4	7.36

Table 25: Point Load Strength of the limestone specimens.

BH No.	Run No.	Specimen No.	Depth (m)	Water Content (%)	Point Load Strength (MPa)	Size Correction Factor	Corrected Point Load Strength $I_{s(50)}$ (MPa)	Correlated UCS (MPa)	Average UCS (MPa)
BH-1	1	16	-6.70	9.71	1.7	1.16	2.0	10.0	**12.8**
	2	17	-8.70	7.28	0.3	1.24	0.4	2.0	
	3	18	-12.80	8.83	0.6	1.03	0.6	3.0	
	4	19	-17.40	19.02	3.5	1.30	4.6	23.0	
	5	20	-18.90	18.87	1.2	1.19	1.5	7.5	
	6	21	-23.00	19.72	1.2	1.25	1.6	8.0	
	8	22	-28.20	15.23	2.1	1.26	2.6	13.0	
	10	23	-33.40	17.11	2.9	1.31	3.8	19.0	
	11	24	-37.00	19.31	2.4	1.29	3.1	15.5	
	12	25	-38.90	10.98	3.8	1.26	4.8	24.0	
	13	26	-43.30	7.94	2.7	1.29	3.5	17.5	
	14	27	-46.90	11.81	3.5	1.27	4.5	22.5	
	15	28	-49.40	19.20	0.3	1.27	0.3	1.5	
BH-3	1	1	-14.10	7.44	8.0	1.34	10.8	54.0	**24.6**
	2	2	-16.40	9.96	3.3	1.23	4.1	20.5	
	3	3	-19.80	16.51	3.4	1.28	4.3	21.5	
	4	4	-21.40	12.22	2.2	1.29	2.9	14.5	
	5	5	-24.70	13.37	2.8	1.28	3.6	18.0	
	6	6	-29.40	15.75	1.9	1.22	2.3	11.5	
	7	7	-30.80	20.18	2.7	1.34	3.7	18.5	
	8	8	-33.85	15.92	2.3	1.26	2.8	14.0	
	9	9	-37.85	8.7	2.8	1.24	3.4	17.0	
	10	10	-39.85	9.81	6.8	1.31	8.8	44.0	
	12	11	-45.55	32.83	0.4	1.32	0.6	3.0	

BH No.	Run No.	Specimen No.	Depth (m)	Water Content (%)	Point Load Strength (MPa)	Size Correction Factor	Corrected Point Load Strength $I_{s(50)}$ (MPa)	Correlated UCS (MPa)	Average UCS (MPa)
	12	12	-47.10	15.31	5.5	1.42	7.8	39.0	
	13	13	-49.60	8.3	7.4	1.32	9.7	48.5	
	14	14	-53.75	18.66	2.5	1.33	3.3	16.5	
	15	15	-55.60	14.71	4.4	1.28	5.7	28.5	

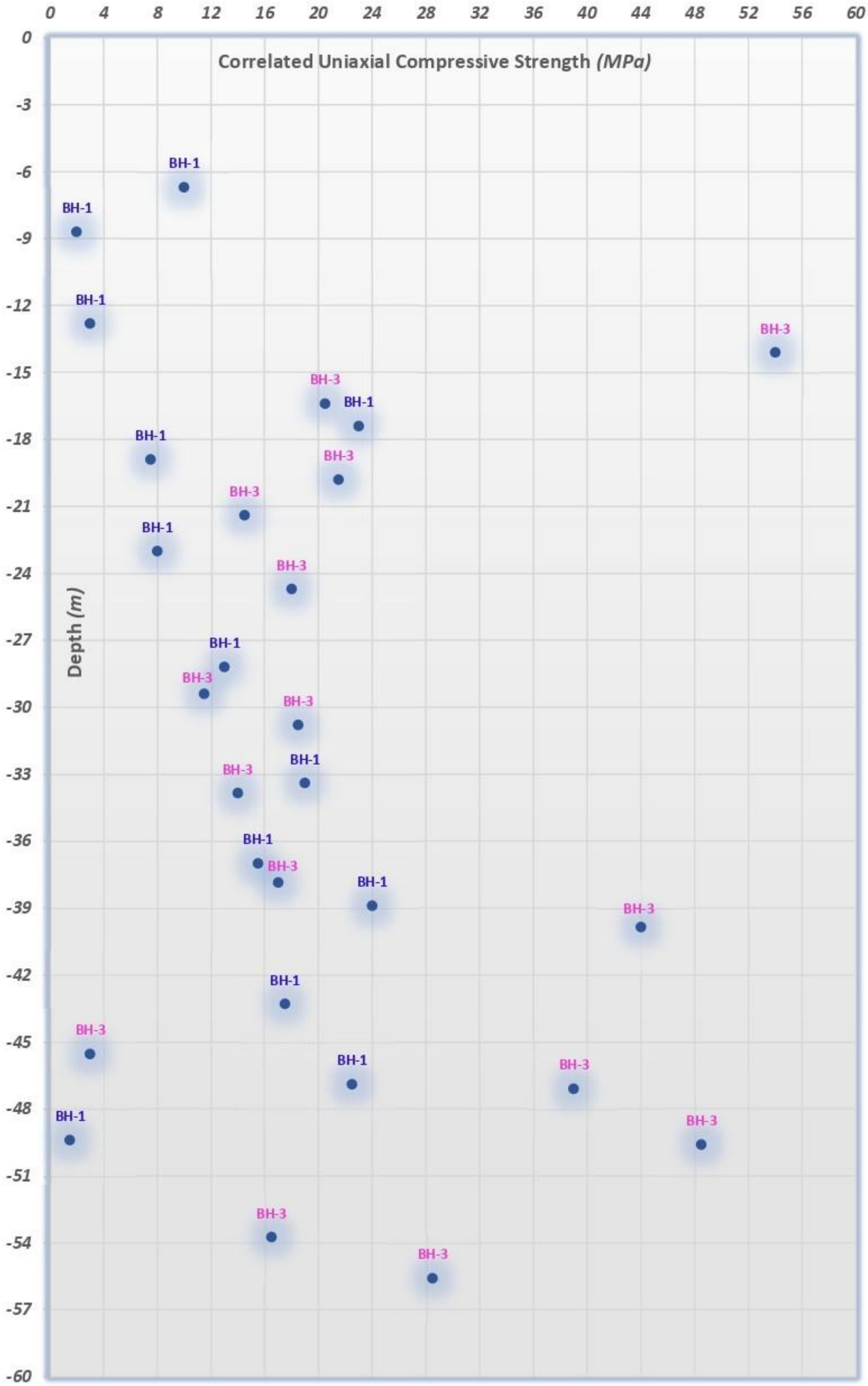


Figure 47: Scatter diagram of correlated unconfined compression test results per depth.

5.3.8.9 Analysis of Rock Strength using RocData

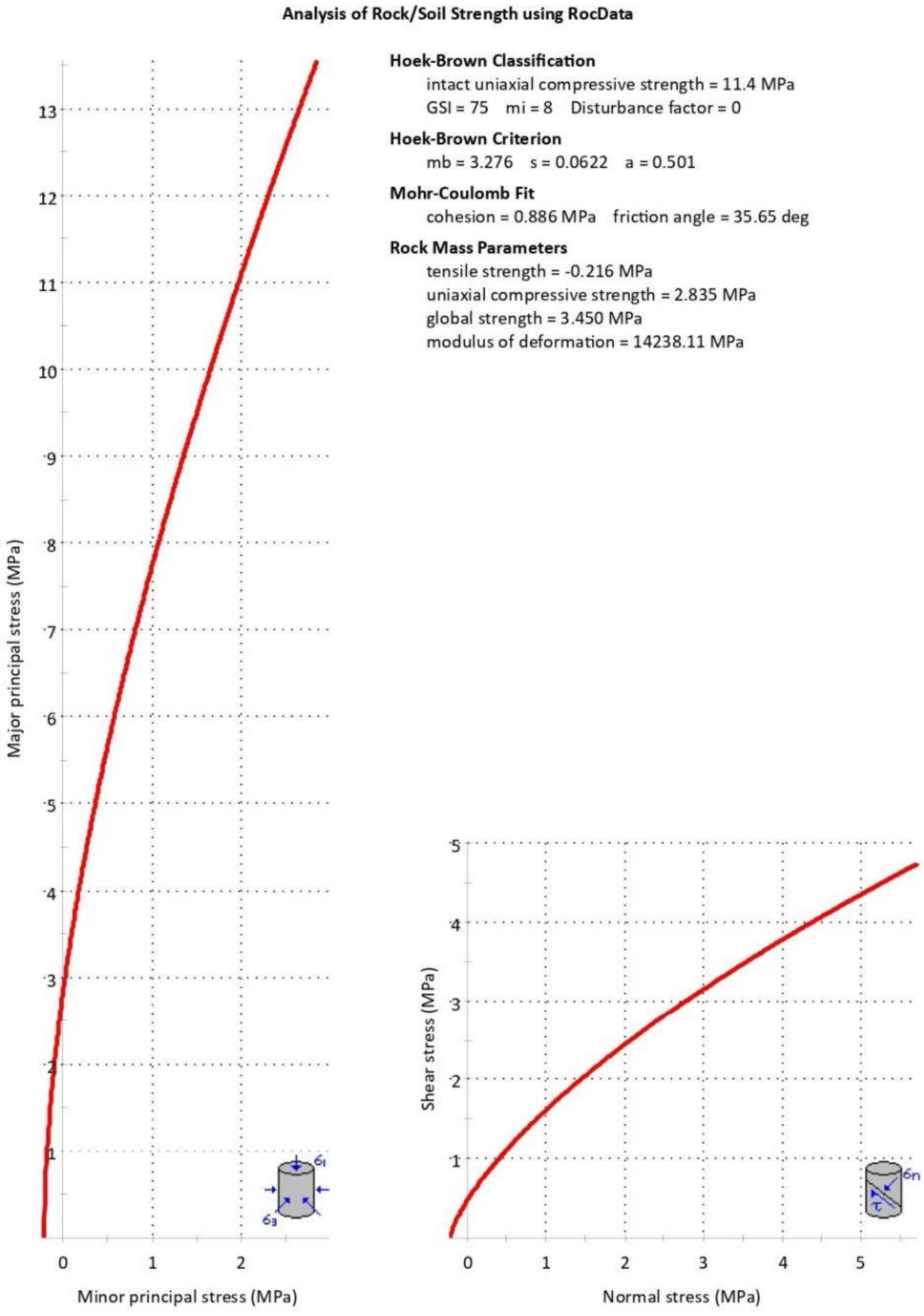


Figure 48: Rock Strength Analysis.

5.3.8.10 Bearing Capacity

Bearing capacity failures of structures founded on rock masses are dependent upon joint spacing with respect to foundation width, joint orientation, joint condition (open or closed), and rock type. Figure 49 and Figure 50 **b**elow, illustrates typical failure modes according to rock mass conditions as modified from suggested modes by Sowers (1979) and Kulhawy and Goodman (1980). Prototype failure modes may actually consist of a combination of modes.

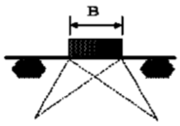
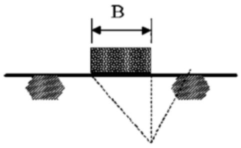
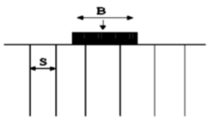
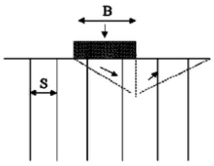
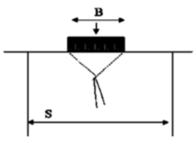
Rock Mass Conditions			Failure		Bearing Capacity Equation No.
	Joint Dip	Joint Spacing	Illustration	Mode	
INTACT	N/A	S>B	 (a)	Brittle rock : Local shear failure caused by localized brittle fracture.	Eq. (4)
			 (b)	Ductile rock: General shear failure along well defined failure surfaces (s).	Eq. (7)
STEEPLY DIPPING JOINTS	70°<α<90°	S<B	 (c)	Open joints: Compressive failure of individual rock columns. Near vertical joint sets (s).	Eq. (5)
			 (d)	Closed Joints: General shear failure along well defined failure surfaces. Near vertical joints (s)	Eq. (1)
		S>B	 (e)	Open or Closed Joints: Failure initiated by splitting leading to general shear failure. Near vertical joint set (s).	Eq. (6)

Figure 49: Typical bearing capacity failure modes associated with various rock mass conditions.

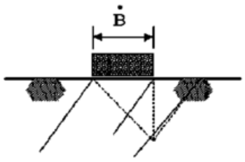
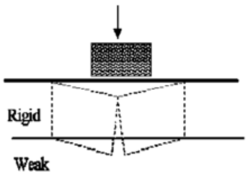
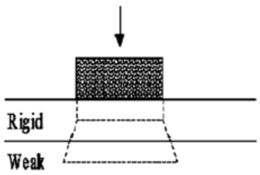
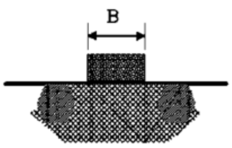
Rock Mass Conditions			Failure		Bearing Capacity Equation No.
	Joint Dip	Joint Spacing	Illustration	Mode	
JOINTED	20°<α<70°	S<B or S>B	 (f)	General shear failure with potential for failure along joints. Moderately dipping joint set (s).	Eq. (2)
LAYERED	0°<α<20°	S>B	 (g)	Thin rigid upper layer : Failure is initiated by tensile failure caused by flexure of thin rigid upper layer.	N/A
LAYERED	0°<α<20°	Limiting values of m with respect to B	 (h)	Thin upper rigid layer : Failure is initiated by punching tensile failure of the thin rigid upper layer.	N/A
FRACTURED	N/A	S<<B	 (i)	General shear failure with irregular failure surface through rock mass. Two or more closely spaced joint sets.	Eq. (3)

Figure 50: Typical bearing capacity failure modes associated with various rock mass conditions.

a. Ultimate bearing capacity. The ultimate bearing capacity is defined as the average load per unit area required to produce failure by rupture of a supporting soil or rock mass.

b. Allowable bearing capacity value. The allowable bearing capacity value is defined as the maximum pressure that can be permitted on a foundation soil (rock mass), giving consideration to all pertinent factors, with adequate safety against rupture of the soil mass (rock mass) or movement of the foundation of such magnitude that the structure is impaired.

The most commonly used bearing capacity equation is that equation developed by Terzaghi (1943).

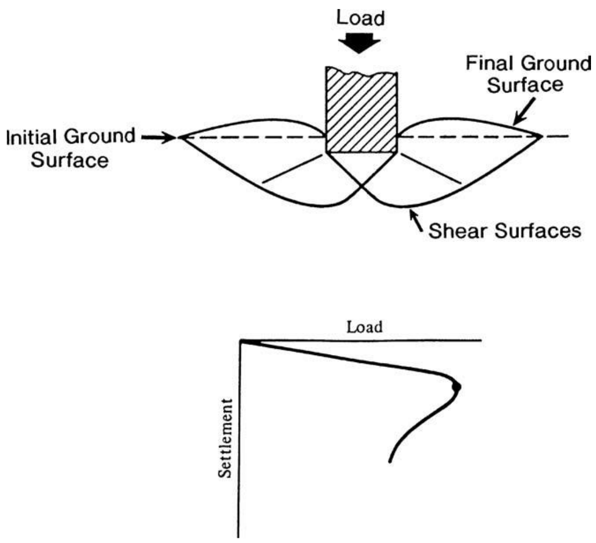


Figure 51: General shear foundation failure. (After Vesic, 1963.)

For a uniform vertical loading of a strip footing, Terzaghi (1943) assumed a general shear failure **(**Figure 52 and Figure 53) in order to develop the following bearing capacity equation:

$$\mathbf{q_{ult} = Q_{ult}/BL = cN_c + 0.5\gamma_t BN_\gamma + \gamma_t D_f N_q}$$

where q_{ult} = ultimate bearing capacity for a strip footing (kPa)

Q_{ult} = vertical concentric load causing a general shear failure of the underlying rock/soil (kN)

B = width of the strip footing (m)

L = length of the strip footing (m)

γ_t = total unit weight of the soil (kN/m^3)

D_f = vertical distance from ground surface to bottom of strip footing (m)

c = cohesion of the soil underlying the strip footing (kPa)

N_c, N_γ, and N_q = dimensionless bearing capacity factors

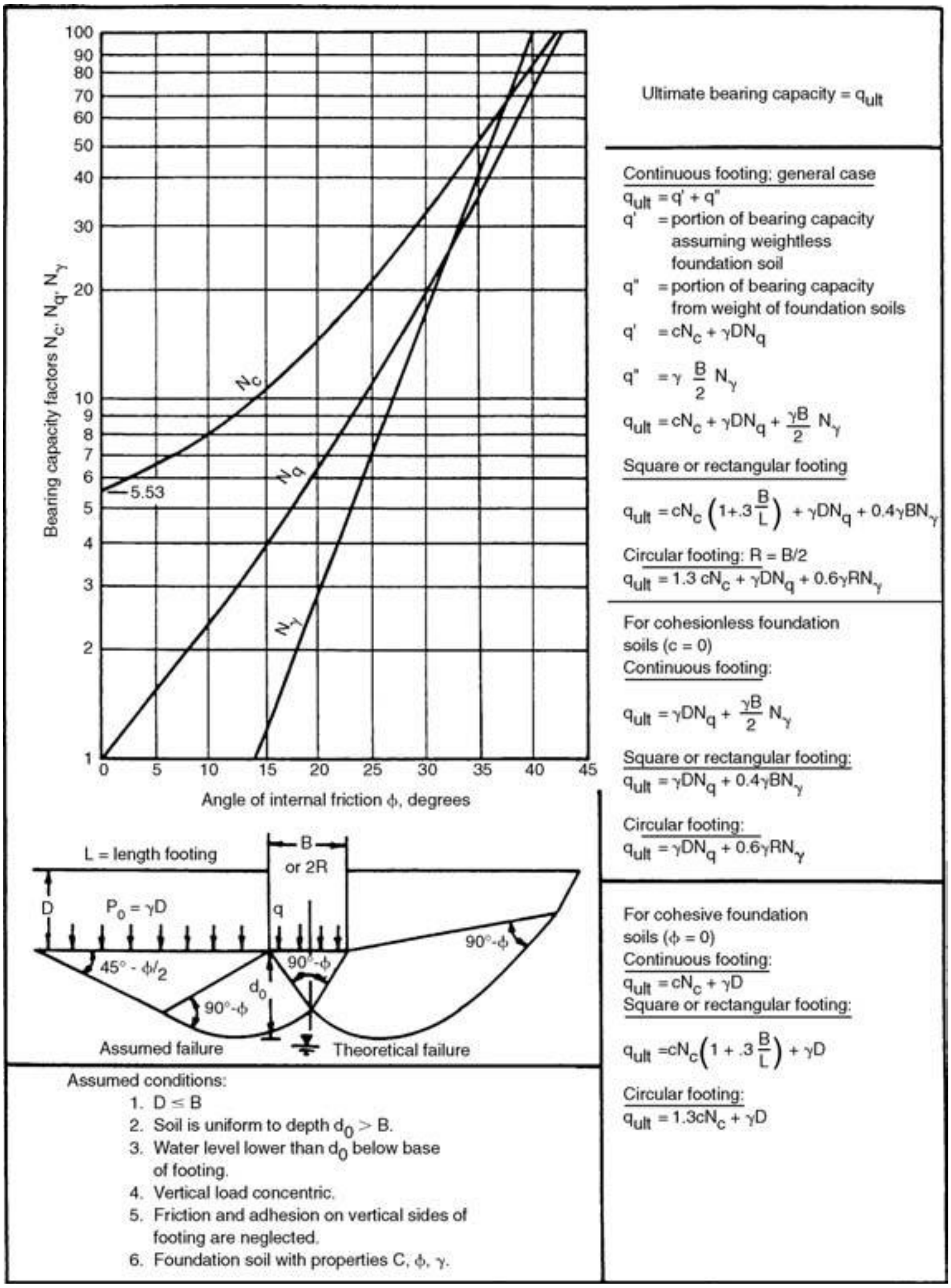


Figure 52: Bearing capacity factors N_γ, N_c and N_q.

No foundation details of the proposed development have been provided. Therefore, having no information on the loads, shapes and sizes of the foundations, an estimate of the presumed allowable bearing pressure for foundations placed directly on the encountered rock is provided for the following assumed case. The foundation depth assumed at <u>-2.00m below the seabed</u>.

Foundation Depth D_f=2.00m below the seabed.

- Cohesion = 110kN/m^2
- Friction angle ϕ = 35.5^0
- Unit weight = 19.15kN/m^3
- **D_f = 2.00m**
- N_c = 60.55, N_q = 44.19, N_γ = 51.73

Ultimate Bearing Capacity, q_{ult} :	6.28MPa
Factor of Safety, FS :	3
Allowable Bearing Pressure at foundation level, q_{all} :	**2.09MPa**

5.3.8.11 Conclusions

1. The site investigation carried out at Il-Maghtab, Naxxar comprised the drilling of Two (2) sea-based boreholes with full recovery.
2. The recovered rock core consists of "Poor" to "Excellent" quality, blocky, weak to medium strong, Lower Coralline Limestone.
   - Rock Quality, ***RQD=72%*** *(Good, taken as an average)*
   - Geological Strength Index, ***GSI=75*** *(Blocky)*
   - Rock Mass Rating, ***RMR=48*** *(Class III-Fair Rock)*
3. No voids were detected during drilling.
4. Twenty-six (26) specimens of Lower Coralline Limestone were selected from various depths along the recovered rock cores, for Unconfined Compressive Strength (UCS) testing and Twenty-eight (28) specimens for Determination of Point Load Strength. The UCS of the tested Limestone ranged from **1.6MPa** to **28.6MPa**.
5. A presumed allowable bearing pressure for foundations placed at -2.00m below the seabed, directly on the encountered Lower Coralline Limestone Formation is **2.09MPa**.
6. This recommended allowable bearing pressure does not apply to foundations located on fractured rock, or at the upper edge of a vertical excavation face and any of these foundations would have to be considered on a case-by-case basis.

5.4 Cable Route At Landfall- Description

Results of the marine survey show that the area selected for cable landfall is characterised by the presence of a rocky outcrop (lower Coralline Limestone Formation), stretched along the coastline for approximately 600m/1000m, gently sloping (values around 3°), up to a WD of -27/- 28m. The rocky seafloor is almost entirely covered by a dense meadow of *Posidonia oceanica*. Scattered vegetation areas have been detected also outside the NE boundary of the ridge.

Posidonia seagrass beds are protected habitats which have a fundamental role for the health and productivity of Mediterranean marine ecosystems. Conservation of these areas is one of the most important priorities of Mediterranean Sea. The biological resources and ecological services provided by sea grasses are based on the physical structure of the plants themselves and the underwater meadows they form.

The driver in the selection of the offshore route and trenchless drilling path, is to minimize the impact on the surrounding environment, trying to avoid, as much as possible, seabed unevenness and interferences with protected habitats. For this purpose, a trenchless tunnel shall be drilled at landfall using a Horizontal Directional Drilling (HDD) Machine (Figure 53).

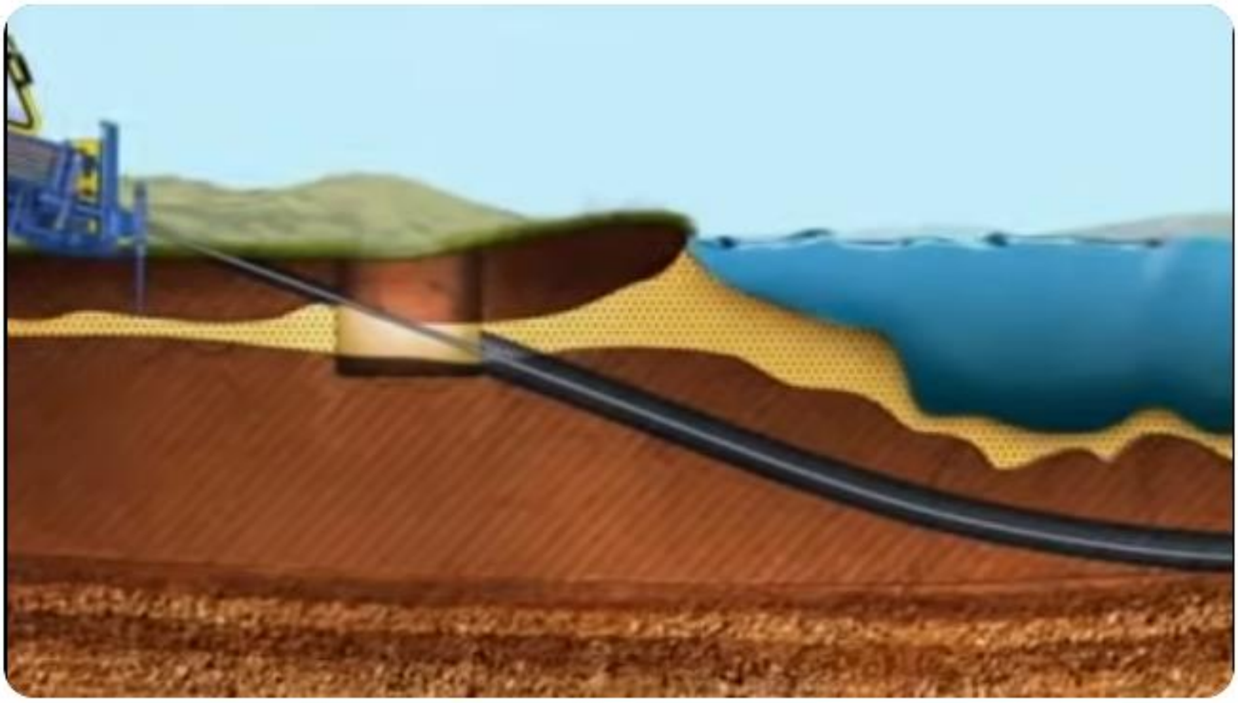


Figure 53: Picture showing a subsea horizontal hole drilled by an HDD Machine(https://www.youtube.com/watch?v=lzVgoa5TBKw)

5.4.1 Choice of the HDD route

Minimisation of mud dispersion at sea

Besides a number of technical requirements, an important requirement that must be considered, is relevant to the dispersion of the drilling fluids such as bentonite mud, which should be minimized. Furthermore, for technical reasons, the water depth at the exit point of the HDD hole to be drilled from an onshore platform should be not more than -10m.

An effective way of achieving fluid containment is the installation of a casing pipe into the seafloor at exit point from a jack-up barge or fixed vessel. This will allow for drilling fluid to be recovered up through the casing, recycled and pumped downhole to the Bottom Hole Assembly. The casing not only provides containment, it also adds stability to the drill pipes as it spans from the work platform down through the seabed.

Of the three alternative considered, Alternative #1 (in red) was chosen, for technical reasons and to avoid as much as possible the negative impact on the Posidonia Meadows. The profile of this route is shown in Figure 55.

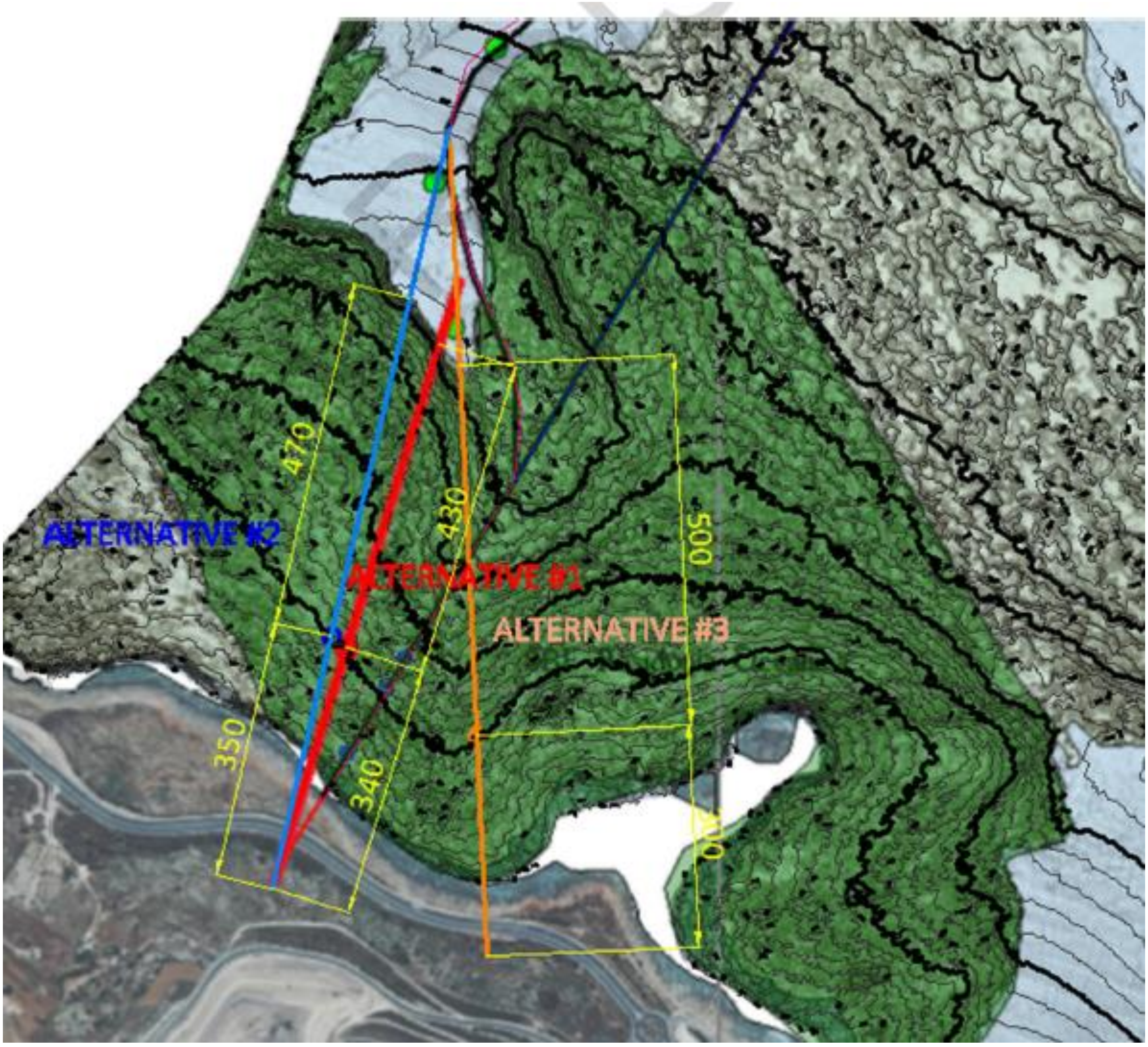


Figure 54: Map showing the three alternative routes considered for the Trenchless HDD microtunnel. The route chosen is shown in red

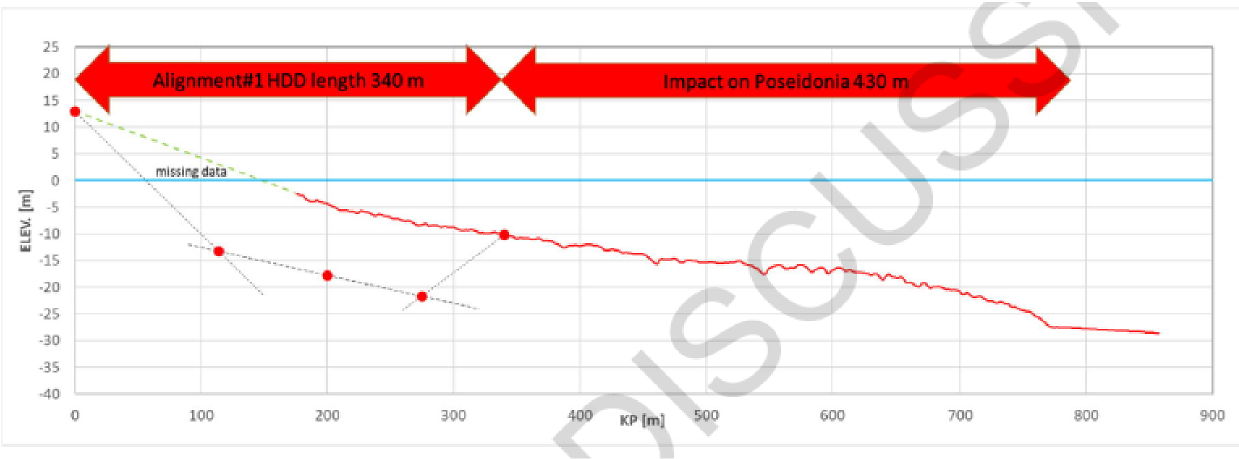


Figure 55: Alternative Route #1- Impact on seabed profile

5.5 Geology

5.5.1 Stratigraphy

The five Late Tertiary rock formations exposed on the Maltese Islands are, from base to top (Figure 56):

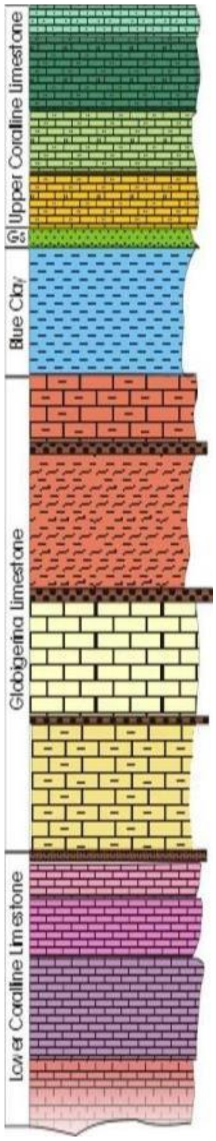


Figure 56: Stratigraphic column

- Lower Coralline Limestone Fm (oldest)
- Globigerina Limestone Fm
- Blue Clay Fm
- Greensand Fm
- Upper Coralline Limestone Fm (youngest)

In addition to these formations, Quaternary continental deposits are also known to occur sporadically on the Maltese Islands. An unconformity and an erosional surface separate this unit from the underlying marine sedimentary succession.

The rock formations preserved in the Study Area are (Figure 57)

- Lower Coralline Limestone Formation
- Globigerina Limestone Formation –Lower Globigerina Limestone Mb.

At the site the exposed rock units are the Lower Globigerina Limestone Mb underlain by the Xlendi Mb and Attard Mb of the Lower Coralline Limestone Formation.

Some partly lithified red Quaternary slope deposits related to a local fault, have been identified on the hill slope east of the site close to the coast road.

The interconnector will make landfall north of the Ghallis rocks through a trenchless duct. Initially it will cross bare rock exposing Lower Coralline Limestone. Then it will follow the northern and western perimeter road to the Enemalta Terminal (Figure 58) where trenching works appear to be mostly in landfill.

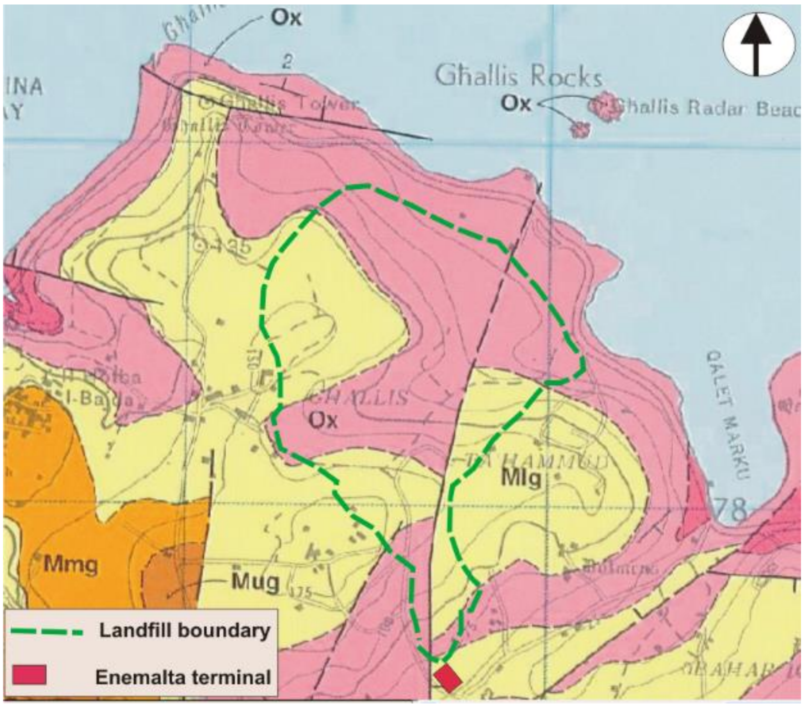


Figure 57: Geological map of Maghtab and il-Ghallis with the landfill boundary superposed ; Mlg: Lower Globigerina Limestone Mb; Ox: Lower Coralline Limestone Fm-Xlendi Mb; Oa: Attard Mb

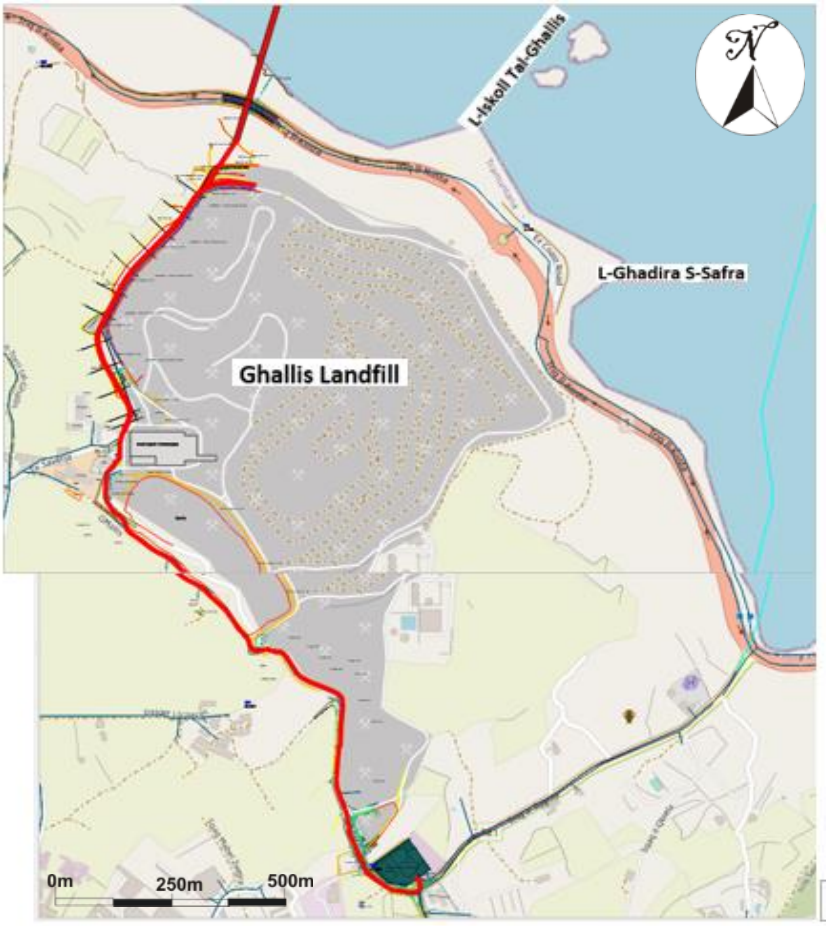


Figure 58: Map showing the onshore route taken by the electrical interconnector (IC2)

5.5.1.1 Lower Coralline Limestone

As its name implies the Lower Coralline Limestone Formation is the lowermost rock formation exposed on the Maltese Islands. It outcrops some 400m to the east of the site.

The formation is known to be over 140m thick. Although the base of the formation is taken at sea level, it extends lower down below sea level. The contact with the overlying Globigerina Limestone Formation is sharp and is represented by a hard ground. This is best seen at about 1000m away from the site, along the Coast Road.

The Maltese name is Zonqor or Blat tal-Qawwi usually further classified as: First quality tal-Prima and second quality tas-Seconda.

SUB-DIVISIONS

The rock formation has been subdivided into four members as follows (Pedley, 1978):

- Wied Maghlaq Member (oldest)
- Attard Member
- Xlendi Member
- Il-Mara Member (youngest)

5.5.1.2 Attard Member

The Attard Member is predominantly composed of massive white algal limestone in 1m to 3m thick beds.

5.5.1.3 The Xlendi Mb

Of these members the rock that dominates the area of influence is the Xlendi Member , which from past ground investigations in the area is known to be about 9m to 11m thick and is composed of brown or light brown very coarse bedded foraminiferal Limestone in wedge –shaped mega-foresets beds of 20cm to about 80cm thick (Figure 59 and Figure 60).

Figure 59: Coast Road cutting about 4m high exposing strata of the Xlendi Mb

Figure 60: Photograph showing Xlendi Mb with Karst conduits filled with terra rossa

5.5.1.4 Mara Member

This rock unit is absent from north Malta. The Name il-Mara derives from the locality of il-Mara in eastern Malta where this member is best developed and was accessible in a Quarry cut in the cliff face and which now has been backfilled with fly ash. Best exposures lie along the Xghajra coastline. It is composed of massive bedded pale-yellow limestone characterised by the giant foraminifera known as *Lepidocyclina.*

At the site this rock unit is represented by a condensed sequence composed of very hard brown bed about 0.5m thick. It is overlain by the Lower Globigerina Limestone.

5.5.1.5 Globigerina Limestone Formation

This rock formation is usually subdivided into (Rizzo1932):

- Lower Globigerina Limestone
- Middle Globigerina Limestone
- Upper Globigerina Limestone

Phosphate pebble bed or conglomerates mark the contact between the Lower and Middle Globigerina and the contact between the Middle and Upper Globigerina Limestone Members.

Of the three rock units that make up this rock formation, only the Lower Globigerina Limestone Mb is present in the Study Area.

5.5.1.6 Lower Globigerina Limestone Member

It consists of pale yellow brown to yellow fine to medium- grained weak, massive, often intensely bioturbated limestone. A thin phosphate pebble bed (Sometimes two) and scour surface is developed at the top of the Lower Coralline Limestone. The rock is composed of whole and fragmented tests of microforaminifera. The macrofossils usually present are echinoid spines and echinoid tests and whole or fragmented bivalve shells. Trace fossils are commonly represented by *Thalassinoides*.

This rock unit is marked by a series of terraced fields which are absent from Lower Coralline Limestone exposures. It Is now mostly buried under the Maghtab and Ghallis landfill (**Figure 62**).

5.5.1.7 Quaternary deposits

During the Field survey a red partly lithified slope scree exposure was observed along the coast road (Figure 62Figure 61). The slope scree is associated with minor faulting which can be seen along the coast road.

Figure 61: Cutting in the Ghallis Land fill showing the contact between Lower Coralline Limestone and the overlying Lower Globigerina Limestone marked by two slightly darker yellow beds

Figure 62: Photograph showing a surface lithified layer of red quaternary slope deposits underlain by Lower Globigerina Limestone. Such deposits are usually associated with a fault

5.5.2 *Structural Geology*

The uplands adjacent to the site are known as the Ghallis high as despite their location on the hanging wall of the Victoria Lines Fault, the Lower Coralline Limestone rises way above sea level. The high is dissected by a radial drainage system of which, *wied ta' Kieli* and Wied tal-Ghallis are the most relevant to this report.

One fault can be seen traversing the landfill (see Geological map) other minor faults can now be seen in the coast road cutting, exposing a thin bed of Lower Globigerina Limestone located in a shallow graben bounded by two normal faults having a throw of a few metres. This also explains the preservation of a thin Quaternary slope deposit within the graben.

Many Quaternary slope deposits are associated with such faults. In the absence of faults usually no Quaternary slope scree deposits are preserved.

Figure 63: Roadside exposure showing a normal fault and structural contact between Lower Globigerina Limestone and Lower Coralline Limestone

5.6 Assessment of the Offshore and Onshore Stone Material to be Excavated

The modality of the laying of the Interconnector cable shall be as follows:

- Ploughed/Jetted trench in soft sediments on the seabed without extraction of any sediment or stone material.

- Trenchless Duct , in Lower Coralline Limestone at landfall about 300m long cut by means of a cutter which will yield a volume of rock cuttings.

- An onshore trench about 1.7m deep which will be cut partly in bare rock for about 100m and the rest will be cut in landfill of the perimeter road.

According to data provided by InterConnect Malta the quantity of material to be excavated shall be around 4,500Cu m. This includes material derived from the Horizontal directional drilling, Joint bay excavation and trench.

Minimal waste quantities shall be generated during the operation stage.

5.6.1 Rock quality

Ground investigation at the landfall both onshore and offshore have shown that:

- The rock quality is expected to be good
- Rock strength is expected to be weak to medium strong (BS5930: 2015).

5.6.2 Use of stone material

Lower Coralline Limestone extracted may be used as an aggregate for the production of concrete.

Quantities of Lower Globigerina Limestone that may be excavated in trenching works on the perimeter road of the landfill may be used in mass concrete.

5.6.3 Slope Stability

5.6.4 Landfill

Landfill Slope stability. A road runs along the north-western boundary of the site and separated the site from the landfill. The toe of the landfill is protected by a thick concrete gravity wall. The land fill itself is terraced and set in benches each about 15m high with a 5m wide step for every 15m increase in altitude. The average slope angle is about 16 Degrees (Figure 64). The angle of repose for landfill material is usually of the order of 45Deg (Table 26). This setup of the slope renders it quite stable. In fact, no land slip has ever been recorded at the Maghtab-Ghallis landfill.

Landfill slope stability is therefore not considered an issue considering that the landfill slope is 1/3 (one third) that of the angle of repose.

5.6.5 Overburden stability

Onshore trenching works shall be about 1.7m deep. Caution should be exercised as land fill material and soil can be unstable in vertical cuttings even though the depth is shallow.

Excavation in rock: The face of the excavation should be monitored for potential formation of unstable rock wedges that may arise due to intersecting fissures, that may daylight in the rock face during excavation. These should be stabilized by rock bolting.

Figure 64: NW-SE Cross-section across the Ghallis Maghtab Landfill (Purple line). Line of section is the green line shown in the Google Image.

Furthermore, the landfill has been in existence for over 20 years and no landslip has ever been recorded.

Table 26: Angle of repose of some natural materials-Crushed stone has a value of 45Degrees-https://en.wikipedia.org/wiki/Clover

Material (condition)	***Angle of Repose* (degrees)**
Sand (wet)	45°
Sand (water filled)	15–30°
Sand (dry)	34°
Gravel (natural w/ sand)	25–30°
Gravel (crushed stone)	45°
Granite	35–40°
Earth	30–45°

5.7 *Geomorphology of the Landfill Region*

The area under study is a low and broad spur of agricultural land at the foot of the landfill hill, which from the site at about 40m above sea level rises to about 60m to reach a height of 100m above sea level. The site developed mainly on Globigerina Limestone. The Lower Coralline Limestone (Xlendi Mb and Attard Mb) weathers only by solution and as it is almost pure Calcium Carbonate. For this reason, no substantial soil thickness is developed on this rock formation. Such limestone pavement is usually designated as "*Xaghra*". In other areas exposures of the Xlendi Mb are mostly bare. The soil covering rock exposures of thE XLENDI MB below the site must have been transported.

The geomorphological features that once could be seen in the Study Area are listed

below (Figure 65):

- Saddle at Ta' San Pietru
- The Il-Qadi –Ta'Hammud Uplands flanked by
- Wied Maghtab on the East and
  - Il-Qadi - Ta' Hammud Uplands
  - Wied Ghallis Valley
  - Wied ta'KIeli Valley
  - The pocket beach of Qalet Marku
  - The Bahar ic-Caghaq – Ghallis rocky coastline

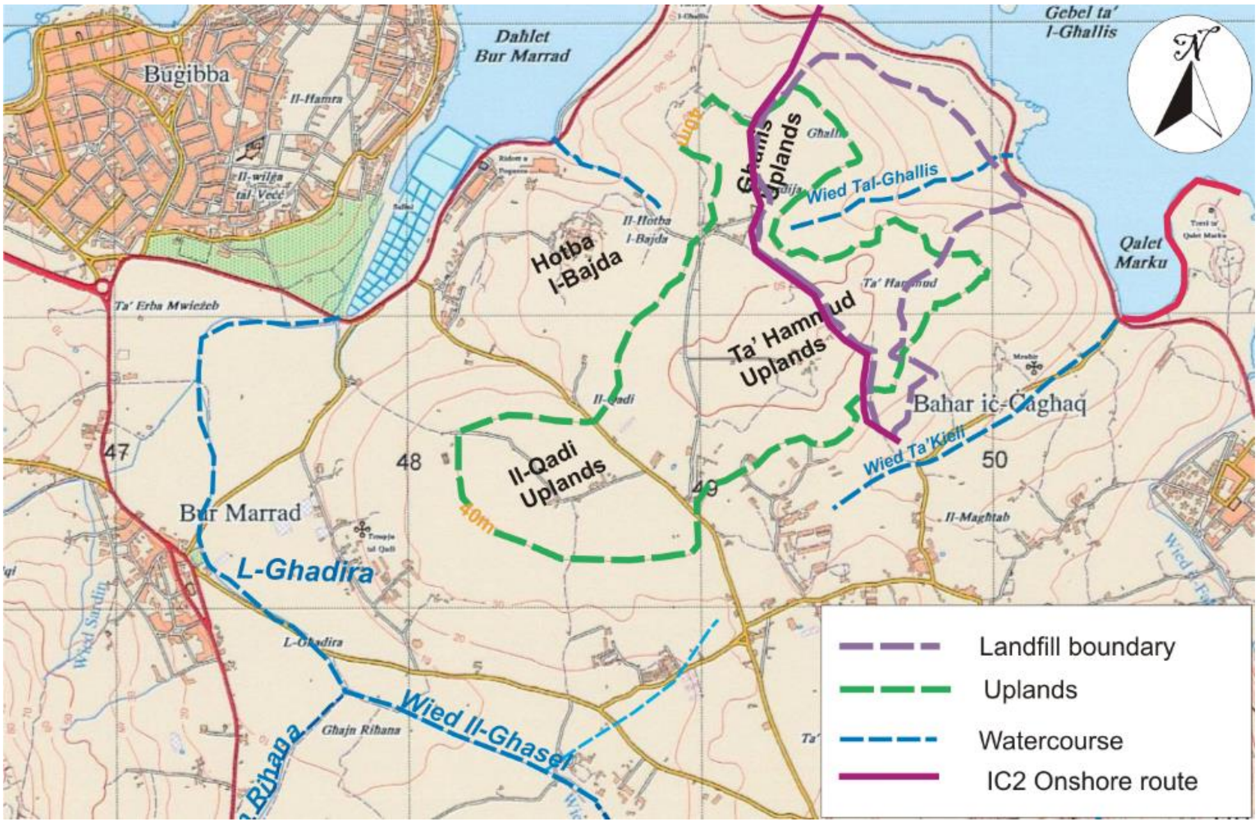


Figure 65: Map showing the onshore geomorphology. For scale grid squares measure 1000m by 1000m

Most of these features are now buried beneath the Maghtab – and Ghallis Landfill and what remains are:

- *Wied Ta Kieli a primarily agricultural tenement parcelled into terraced fields. No watercourse is developed except at the coastline*
- The eastern slopes of Ta Hammud Uplands. The upper sector of these rounded slopes is terraced and covered by a topsoil while the lower part which exposes Lower Coralline Limestone constitutes mainly a limestone pavement as inland exposures of Lower Coralline Limestone , being a pure limestone, are barren and form a limestone pavements locally known as *xaghra*.
- The Qalet Marku Ghallis Coastline is set on the Xlendi mb of the lower coralline limestone Formation. The coastal belt that forms a corridor between the coast road and the coastline is characterised by its serrated character and rugged marine karst landscape forming a dense network of rock pools up to about 5m in diameter (Figure 66). It is a rugged bare shore platform with scattered ponds best represented by ix-Xaghra S-Safra. Shallow embayments form the offshore extension of the valleys mainly represented by Bahar Ic-Caghaq and Qalet Marku.

Figure 66: Typical rock pool morphology of the coastline as seen along the Ghallis coast road

5.7.1 Geomorphology and structural geology

In structural Geologically these uplands are known as the Ghallis high as despite their location on the hanging wall of the Victoria Lines Fault, the Lower Coralline Limestone rises way above sea level. The high is dissected by a radial drainage system of which, Wied ta' Kieli and Wied tal-Ghallis are the most relevant to *this report*.

The site is located next to broad spur roughly oriented North South and forms part of the Ghallis structural high. This High is marked by a well developed Lower Coralline Limestone with a reduced thickness of the Globigerina Limestone. Past ground investigation has revealed that the Lower Globigerina Limestone and the Lower Coralline Limestone are over 50m thick.

5.7.2 Soils of the Maltese Islands

SOIL COMPOSITION - The most striking characteristic of the soil of the Maltese islands is their high carbonate content along the whole soil profile. For example, it is of the order of 50 % to 80% near the surface of the pale brown soils (Xerorendzinas) and in the white raw carbonate soils and is found to increase down the soil profile, whereas in the terra rossa soils (red) it ranges from 25% to 60% and decreases with depth.

SOIL DEPTH - The depth of soil or soil-like material is very variable and is found to be highly dependent on the morphology of the area under consideration as well as on the underlying bedrock itself. Generally, its depth is very shallow on ridges plateaus and pavements formed of hard limestones, (erosional surfaces) such as the Lower Coralline Limestone. It usually ranges in depth from less than 20cm to 60cm with the exception of isolated pockets, where it could be deeper. However, very often the hard Coralline limestones are exposed as a bare highly karstified surface.

On the other hand in erosional and structural valleys the soils were developed over slope taluses and alluvial deposits which have been weathered to varying degrees under the influence of past climatic regimes and usually are very thick and often exceed 150cm.

The soils or soil material on talus deposits and Blue Clay outcrops are usually deep as the parent material is soft and can be readily disintegrated into a soil which is barely distinguishable from the humus deficient soil itself which is commonly only about 75cm deep.

5.7.2.1 Terracing And Other Human Interference

Under the local climatic regime of a long dry summer and a short-wet season with frequent heavy showers soils is usually easily eroded. However, this has been prevented by terracing. In fact, over the years, in order to preserve his scanty soil resource, the local farmer has actually remodelled the land surface especially the hill slopes by terracing and building of rubble walls to protect the soil from the agents of erosion. The only areas which have escaped profound human intervention are the nearly level areas of deep soil in the erosional and structural valleys as well as the hard limestone plateaux where the principal human intervention was the construction of rubble walls. However, even here man has re-sculptured the land surface. In these areas the soil was carefully removed the irregular and usually sloping rock outcrop was hewn and levelled and the soil material was carefully and regularly spread over the entire surface. The excess material was usually disposed of by building rubble walls which act as wind breakers as well as prevented run-off water from eroding the soil.

Such terracing has been even more drastic in the globigerina areas as the limestone is very soft and hence man could cut even deeper thus giving rise to terraces separated by a depth interval which could be a metre or two. In these circumstances the scarce soil material has been supplemented by fine rock fragments and rock flour produced during terracing of the hill slopes as well as during the excavation of water reservoirs and building stone quarrying.

Soil material has always been recognised as a scarce resource and the literature refers to the transport of ship- loads of red soil from Sicily for the construction of the Maltese fields during the early days. However, this is very unlikely, the only material that could have been imported was ballast for the ships.

The soils found distributed in the Maltese Islands have been classified into three groups (Lang 1962). These are:

- Terra Rossa
- Xerorenzina
- Carbonate raw Soils

This classification basically corresponds to the local popular names of red, brown and white soils.

5.7.2.2 Terra Rossa

The red Terra Rossa soils are highly decalcified and are rich in humus. The brown Xerorenzina soils are only slightly decalcified and humus enriched. The whitish Carbonate Raw Soils are essentially physically disintegrated parent rock; they are highly calcareous and humus deficient. Within this broad soil classification there exists a wide range in variation due to local natural processes such as mixing of the parent material with products of erosion and deposition by runoff water and soil creep as well as due to local lithological variation within a given formation such as the three members composing the Globigerina Limestone as well as due to lithological variations that occur within each member. These differences are further complicated by human interference such as in manmade soils, terracing and addition of soil coming from other parts of the island.

Considering the local particular conditions, the three classes of soils referred to above have been further subdivided as follows:

5.7.2.3 Xerorenzina

- San Biagio
- Alcol
- Tal-Barrani

5.7.2.4 Terra Rossa

- Tas-Sigra
- Xaghra

Furthermore, one association and three soil complexes have also been identified as follows:

- **Rdum sequence**: a lithosequence occurring on scarp slopes.
- **Armier complex**: a natural soil complex produced by mixed parent material.
- **L'inglin complex**: a man-made complex arising from terracing on steep slopes.
- **Tad-Dawl complex**: a man made complex in quarries.

5.7.3 *The soil at the onshore cable route*

The cable route makes landfall on a Xaghra series type of sol. Lower Coralline Limestone exposures are bare of any soil or it is in patches and very thin and is termed the Xaghra Soil Series.

The remaining cable route on the perimeter of the landfill lies on disturbed ground.

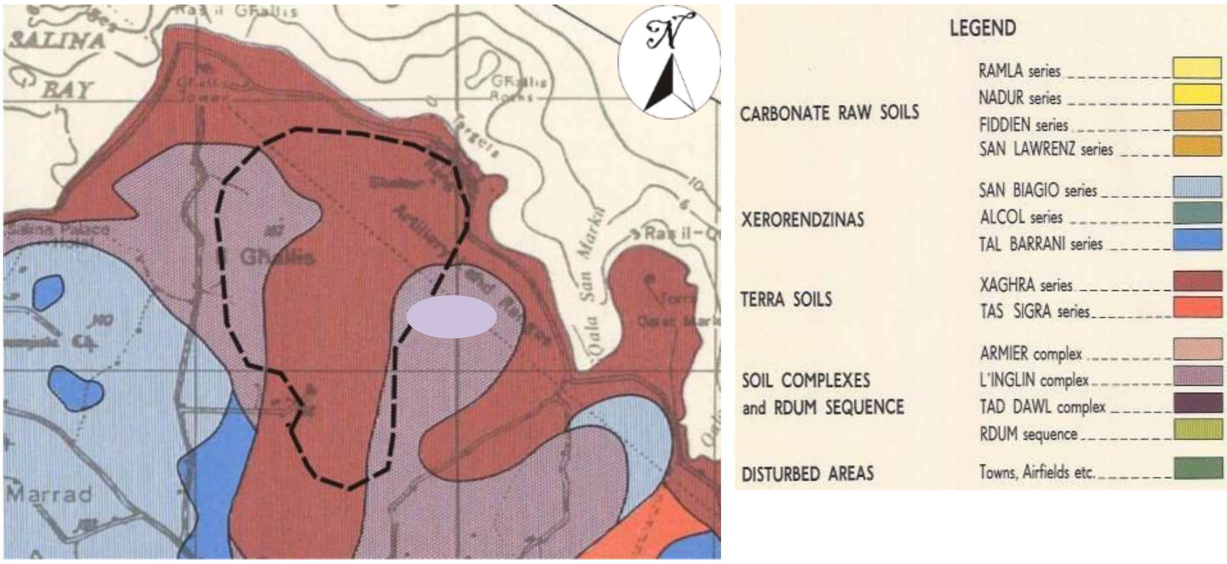


Figure 67: Soil map of the environs of the site from Lang 1962. Black line indicates the approximate extent of the land fill. For scale grid squares are 1km by 1km

XAGHRA SERIES (Terra Rossa) - This soil series is represented by very shallow to very deep, red, heavy textured (clay and clay loam) decalcified soils with a strong subangular to angular blocky structure and occurs intermittently among hard limestone outcrops on the karst landscape. The soils are strongly decalcified, with humus -enriched surface and possess an A C D profile on an almost completely decalcified B horizon soil material formed during an earlier climate.

This soil series is invariably associated with the karst type of landscape. The principal areas of distribution are on the Rabat-Dingli plateau the coastal hills between Sliema and Salina and other areas associated with Lower and Upper Coralline Limestone Formations, and the Franka layer of the Lower Globigerina.

6.0 Results: Hydrology And Hydrogeology

6.1 The Water Protection Zone

The site is underlain by the lower coralline limestone which constitutes the mean sea level aquifer but it does not lie within the boundary of the water protection zone (Figure 68).

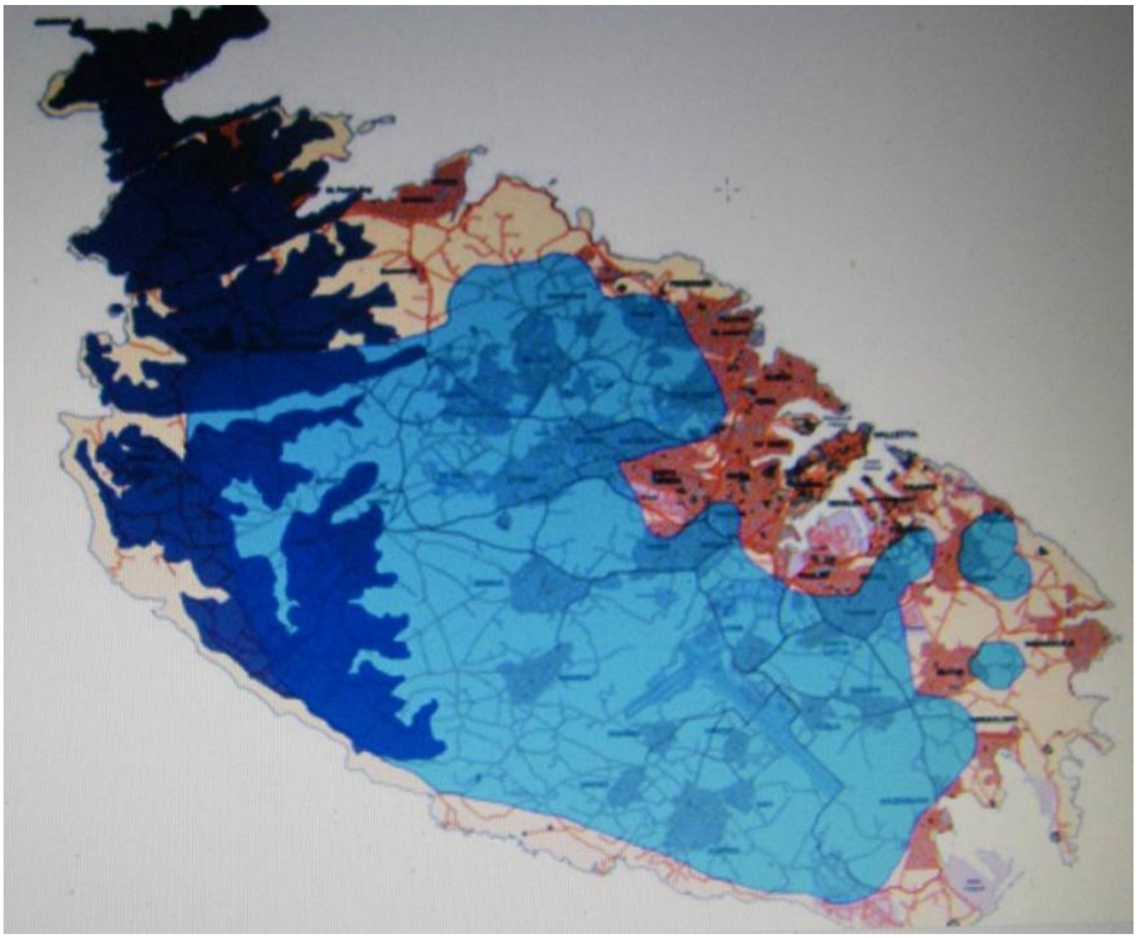


Figure 68: Map showing the water protection zone extending over the island

6.2 Hydrology and Hydrogeology

The site falls within the catchment of Wied tal-Ghallis (Figure 69). The water shed of this watercourse passes just north of the sit e as shown in the map.

The hydrogeological and hydrological features close to the site are shown in Figure 69 and are listed below:

- Wied-tal-Ghallis: a shallow valley covered by landfill and limestone pavement in which no watercourse is developed suggesting scarce run-off episodes.
- Wied ta'Kieli drainage system which discharges into Qalet Marku
- The catchment of the site. The site lies within the catchment of Wied tal-Ghallis. Its catchment is represented by its boundary.
- The mean sea level aquifer
- Water reservoirs

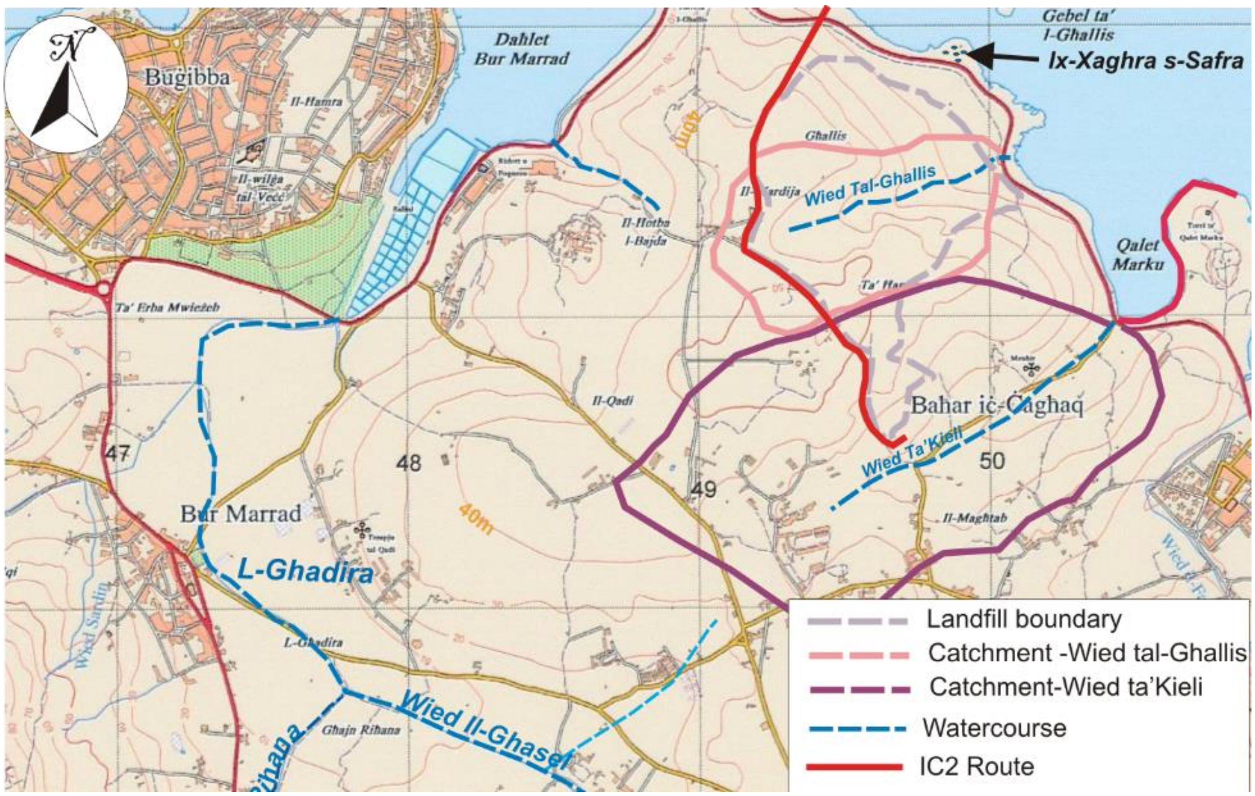


Figure 69: Map showing the catchments of Wied tal-Ghallis and Wied ta'Kieli

6.3 the mean sea level aquifer

Field survey as well as the geological map of the site has revealed that at the site or within its catchment, there are no impermeable beds above sea level such as the Blue Clay Formation. No perched aquifer is therefore, developed beneath the site. The only aquifer beneath the site that may be developed is the mean sea level aquifer, which lies some 30m to 40m below ground level. This also represents the hydrogeological feature closest to the site.

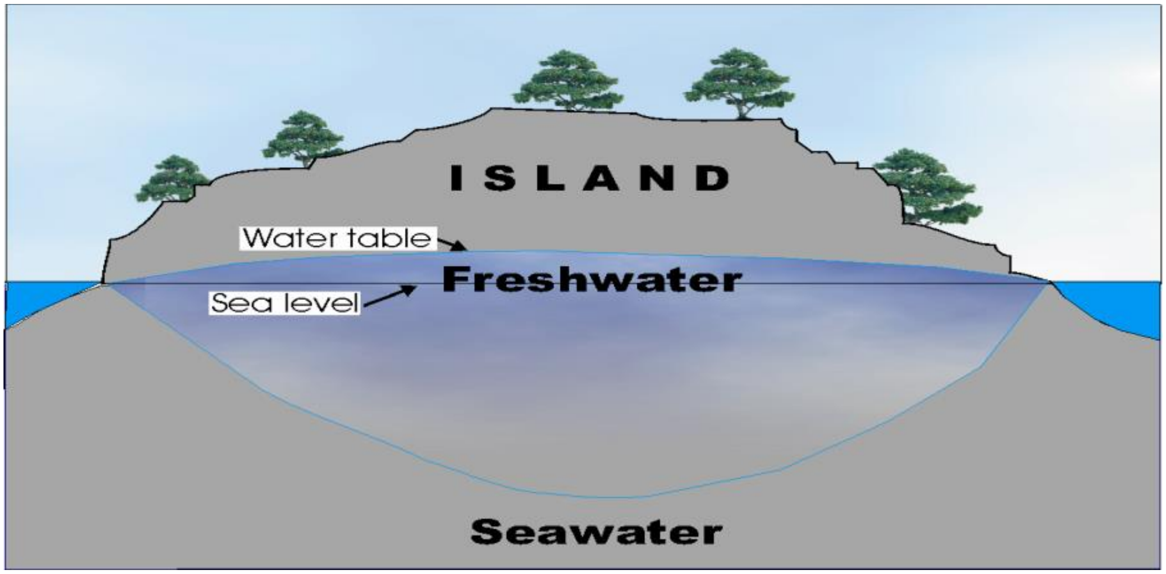


Figure 70: Schematic representation of the mean sea level aquifer developed beneath an island

The sea level aquifer is lens shaped water body reaching some 2.5m above sea level in central Malta and thins out to zero thickness at the coastline (Figure 70).

6.4 Water Boreholes – Water Services Corporation

The area under study lies outside the mean sea level aquifer protection zone. The WSC hydrological feature closest to the site are two boreholes in Wied ta'Kieli (5).

7.0 Cable Route Hazard Assessment (PSA-WP2)

7.1 General

This section presents a summary of the hazards and cable constraints identified along the IC2 cable route and offshore survey area. This section includes:

- A geohazard register for the IC2 cable route;
- Results of the seismological hazard assessment.

(Taken from: FUGRO -220561-R-001 01 | Geological and Seismological Hazard Assessment)

7.2 Geohazard Register

A project geohazard register was created to summarise all geohazards, both geological and anthropogenic, identified or interpreted to be present along the IC2 cable route. The geohazard register is presented in (*Fugro-Geological and Seismological Hazard Assessment -Consultancy Report | Offshore Malta-Italy, Mediterranean Sea 220561-R-001 01 | 3 February 2023 -Draft-Interconnect Malta*).

As part of the project geohazard register, a qualitative assessment of the likelihood and severity of encountering each geohazard was completed. Likelihood is assessed in relation to both the offshore survey area and along the IC2 cable route. This assessment was based on available data only and does not represent a full risk assessment. Table 28 defines the qualitative descriptors used in this assessment.

Distribution of hazards are described in relation to soil zones and KPs along the IC2 cable route.

Table 27: Risk Assessment matrix for the geohazards identified along the Cable route

Table 7.1: Risk assessment matrix for the identified geohazards

SEVERITY	LIKELIHOOD			
	A- None (Geohazard not inferred to be present based on available data)	B- Low (Geohazard inferred to be present but not observed within available data)	C- Moderate (Geohazard inferred to be present and some indicators within available data)	D- High (Geohazard inferred to be present and observed within available data)
1. Mitigation unlikely to be required	Low	Low	Medium	Medium
2. Mitigation using engineering solutions should be considered, but not always needed	Low	Medium	Medium	High
3. Mitigation using engineering solution, possible avoidance recommended	Medium	Medium	High	Very High
4. Mitigations not practical, avoidance strongly recommended	Medium	High	Very High	Very High

Shallow bedrock	Sub-seafloor	Bedrock strata present within the shallow subsurface (5 m BSF). In the offshore survey area, Geophysical Units G and H interpreted to represent bedrock strata and were mapped locally within 5 m BSF in SBP data. Shallow bedrock also interpreted to be present through S01 based on review of SBP data. In the nearshore Malta survey area, localised occurrences of “rocky outcrops” described in SBP data (Fugro, 2022b).	■ Offshore survey area: • Cable soil Zone 1a (KP 1.5 to KP 9.5) • Cable soil Zone 1b (KP 2 to KP 3.5) • Cable soil Zone 5a (KP 72.5 to KP 90) • Cable soil Zone 5b (KP 74.5 to KP 89.5) ■ Nearshore Malta survey area (Fugro, 2023)	3	D	D	■ May require additional engineering consideration for cable design and installation ■ Increased cable installation costs ■ Rock dumping may be required above cable for protection	■ Presence of shallow bedrock in nearshore Italy survey area ■ Low confidence over mapping of Geophysical Units G and H due to quality of SBP data in northern section of cable route. Unmapped areas of bedrock within 5 m BSF may exist across offshore survey area ■ Bedrock strata not sampled by geotechnical data ■ Lithology and geotechnical properties unknown ■ Presence, thickness or geotechnical characteristics of weathered zone
Bedrock outcropping at seafloor	Seafloor	Shallow bedrock outcropping at seafloor. May be exposed or present beneath a thin veneer of surficial sediments	■ Offshore survey area: • Cable soil Zone 1b (KP 2 to KP 3.5) • Cable soil Zone 1b (KP 6 to KP 8) • Cable soil Zone 5b (KP 74.5 to KP 89.5) ■ Nearshore Malta survey area – “rocky outcrops” identified (Fugro, 2023)	3	D	D	■ Potential for increased seafloor gradients ■ May require additional engineering consideration for cable design and installation ■ Increased cable installation costs Rock dumping may be required above cable for protection	■ Areas interpreted as outcropping bedrock not sampled by geotechnical data ■ Lithology and geotechnical properties unknown ■ Presence and thickness of sediment veneer overlying bedrock unknown ■ Presence of outcropping bedrock in nearshore Italy survey area

	Very soft soils	Seafloor and sub-seafloor	Extremely low to low strength, normally consolidated fine-grained silts and clays at seafloor and within 5 m BSF. Geotechnical Units II, III, IVb (silt/clay layers) and V	■ Cable soil Zone 2 (KP 9.5 to KP 36.5 (south) and KP 51.5 to KP 69 (north)) ■ Cable soil Zone 3 (KP 36.5 to KP 51.5) ■ Cable soil Zone 4 (KP 69 to KP 95 (HDD alignment 1) and KP 95.5 (HDD alignment 2)) ■ Cable soil Zone 5a (KP 72.5 to KP 90) ■ Cable soil Zone 6 (KP 95 to KP 96.5 (HDD alignment 1) and KP 95.5 to KP 97 (HDD alignment 2))	2	D	D	■ Engineering implications will depend on chosen method of cable installation ■ Very soft soils that vary in strength along the cable route may prove problematic for surface laid cables ■ If trenched, consideration may be required over trenching method/tools ■ May result in settlement of geotechnical equipment (seabed frame) during site investigation activities ■ Could affect thermal conductivity if present in conjunction with high moisture content
	Dense sands	Seafloor and sub-seafloor	Available geotechnical data enabled identification of very loose to very dense sands within Geotechnical Units 1a and 1b	■ Offshore survey area: • Cable soil Zone 1a (KP 1.5 to KP 9.5) • Cable soil Zone 6 (KP 95 to KP 96.5 (HDD alignment 1) and KP 95.5 to KP 97 (HDD alignment 2)) ■ Nearshore survey areas (Fugro, 2023)	2	D	D	■ May require additional engineering consideration for cable trenching and installation ■ Difficult to penetrate with geotechnical equipment
	Very dense soil layer	Sub-seafloor	Available geotechnical data enabled the identification of a very dense soil layer through S05 and S06 only (Geotechnical Units IVa and IVb)	Cable Soil Zone 3 (KP 36.5 to KP 51.5)	2	D	D	■ May require additional engineering consideration for cable trenching and installation ■ Difficult to penetrate with geotechnical equipment
Shallow bedrock	Sub-seafloor		Bedrock strata present within the shallow subsurface (5 m BSF). In the offshore survey area, Geophysical Units G and H interpreted to represent bedrock strata and were mapped locally within 5 m BSF in SBP data. Shallow bedrock also interpreted to be present through S01 based on review of SBP data. In the nearshore Malta survey area, localised occurrences of "rocky outcrops" described in SBP data (Fugro, 2022b).	■ Offshore survey area: • Cable soil Zone 1a (KP 1.5 to KP 9.5) • Cable soil Zone 1b (KP 2 to KP 3.5) • Cable soil Zone 5a (KP 72.5 to KP 90) • Cable soil Zone 5b (KP 74.5 to KP 89.5) ■ Nearshore Malta survey area (Fugro, 2023)	3	D	D	■ May require additional engineering consideration for cable design and installation ■ Increased cable installation costs ■ Rock dumping may be required above cable for protection

Very soft soils	■ Thermal conductivity of fine-grained soils
Dense sands	■ Extent of dense sands within nearshore survey areas due to absence of geotechnical data here
Very dense soil layer	■ Distribution of layer away from geotechnical locations
Shallow bedrock	■ Presence of shallow bedrock in nearshore Italy survey area ■ Low confidence over mapping of Geophysical Units G and H due to quality of SBP data in northern section of cable route. Unmapped areas of bedrock within 5 m BSF may exist across offshore survey area ■ Bedrock strata not sampled by geotechnical data ■ Lithology and geotechnical properties unknown ■ Presence, thickness or geotechnical

								characteristics of weathered zone
Bedrock outcropping at seafloor	Seafloor	Shallow bedrock outcropping at seafloor. May be exposed or present beneath a thin veneer of surficial sediments	■ Offshore survey area: • Cable soil Zone 1b (KP 2 to KP 3.5) • Cable soil Zone 1b (KP 6 to KP 8) • Cable soil Zone 5b (KP 74.5 to KP 89.5) ■ Nearshore Malta survey area – “rocky outcrops” identified (Fugro, 2023)	3	D	D	■ Potential for increased seafloor gradients ■ May require additional engineering consideration for cable design and installation ■ Increased cable installation costs Rock dumping may be required above cable for protection	■ Areas interpreted as outcropping bedrock not sampled by geotechnical data ■ Lithology and geotechnical properties unknown ■ Presence and thickness of sediment veneer overlying bedrock unknown ■ Presence of outcropping bedrock in nearshore Italy survey area
Very soft soils	Seafloor and sub-seafloor	Extremely low to low strength, normally consolidated fine-grained silts and clays at seafloor and within 5 m BSF. Geotechnical Units II, III, IVb (silt/clay layers) and V	■ Cable soil Zone 2 (KP 9.5 to KP 36.5 (south) and KP 51.5 to KP 69 (north)) ■ Cable soil Zone 3 (KP 36.5 to KP 51.5) ■ Cable soil Zone 4 (KP 69 to KP 95 (HDD alignment 1) and KP 95.5 (HDD alignment 2)) ■ Cable soil Zone 5a (KP 72.5 to KP 90) ■ Cable soil Zone 6 (KP 95 to KP 96.5 (HDD alignment 1) and KP 95.5 to KP 97 (HDD alignment 2))	2	D	D	■ Engineering implications will depend on chosen method of cable installation ■ Very soft soils that vary in strength along the cable route may prove problematic for surface laid cables ■ If trenched, consideration may be required over trenching method/tools ■ May result in settlement of geotechnical equipment (seabed frame) during site investigation activities ■ Could affect thermal conductivity if present in conjunction with high moisture content	■ Thermal conductivity of fine-grained soils
Dense sands	Seafloor and sub-seafloor	Available geotechnical data enabled identification of very loose to very dense sands within Geotechnical Units 1a and 1b	■ Offshore survey area: • Cable soil Zone 1a (KP 1.5 to KP 9.5) • Cable soil Zone 6 (KP 95 to KP 96.5 (HDD alignment 1) and KP 95.5 to KP 97 (HDD alignment 2)) ■ Nearshore survey areas (Fugro, 2023)	2	D	D	■ May require additional engineering consideration for cable trenching and installation ■ Difficult to penetrate with geotechnical equipment	■ Extent of dense sands within nearshore survey areas due to absence of geotechnical data here
Very dense soil layer	Sub-seafloor	Available geotechnical data enabled the identification of a very dense soil layer through S05 and S06 only (Geotechnical Units IVa and IVb)	Cable Soil Zone 3 (KP 36.5 to KP 51.5)	2	D	D	■ May require additional engineering consideration for cable trenching and installation ■ Difficult to penetrate with geotechnical equipment	■ Distribution of layer away from geotechnical locations

Geohazard	Presence (Seafloor/Sub-Seafloor)	Description/Characteristics	Distribution across Cable Route	Severity	Likelihood (Offshore Survey Area)	Likelihood (IC2 Cable Route) *	Engineering Implications	Uncertainties
Coarse material	Seafloor and sub-seafloor	Gravity core and grab samples highlighted the localised presence of coarse material (shell fragments and fragments of coralline algae) in surficial sediments (Geotechnical Unit Ia). Lab testing data on gravity cores suggests percentages are generally low. Potential layers of coarse material were also identified in geophysical data: ■ HIR in SBP data ■ High backscatter in SSS data	■ Cable soil Zone 1a (KP 1.5 to KP 9.5) ■ Potential for coarse material in Cable Soil Zone 6 (Geotechnical Unit Ib) (KP 95 to KP 96.5 (HDD alignment 1) and KP 95.5 to KP 97 (HDD alignment 2))and nearshore survey areas (Fugro, 2023) ■ HIR identified within cable soil Zones 1a, 2, 3, 4 and 5a	1	C	C	■ Variable soil conditions ■ Variable shear strength profiles ■ Dense gravel layers could be difficult to penetrate with geotechnical sampling equipment	■ Uncertainty over whether HIR represents accumulations of coarse material in subsurface
Boulders	Seafloor	Boulders were identified by FISPA using available geophysical data (Fugro, 2022b). Four (4) boulders were identified at seafloor within the offshore survey area. Considered isolated occurrences and not considered a sub-seafloor risk given regional geological history/depositional setting	Boulders identified between: 1. Cable soil Zone 2 (KP 17 and KP 17.5) (approximately 120 m west of the IC2 cable route) 2. Cable soil Zone 2 (KP 23 and KP 23.5) (approximately 50 m west of the IC2 cable route) 3. Cable soil Zone 2 (KP 24 and KP 24.5) (approximately 200 m east of the IC2 cable route) 4. Cable soil Zone 4 (KP 82 and KP 82.5) (approximately 1,800 m west of the planned cable route)	2	D	B	■ Re-routing may be required if boulder is present on planned cable route ■ May cause issues for cable installation and further geotechnical site-investigation activity	■ Precise size, dimensions and lithology of identified boulders ■ Depositional mechanism
Blocks	Seafloor	Area of 'blocks' defined in seafloor sediments mapping, identified by FISPA using available geophysical data and ROV data. Located across escarpment feature. Blocks interpreted as features similar to boulders and thought to comprise bedrock material. Possibly formed as erosional features in association with escarpment. Blocks are not considered a sub-seafloor risk	Cable Soil Zone 1a (KP 6 to KP 7.5)	2	D	C	■ Re-routing may be required if block is present on planned cable route ■ May cause issues for cable installation and further geotechnical site-investigation activity	■ Precise location, size, dimensions and lithology of identified blocks ■ Formation
Shallow gas	Sub-seafloor	Accumulations of gas in the shallow subsurface. Evidence detailed in Section 5.4.3	■ Blanking in SBP data: • Cable soil Zone 1 (KP 5.5 to KP 6.5) Cable soil Zone 3 (KP 45.5 to KP 47) ■ Gas fronts in SBP data: • Cable soil Zone 4 (KP 90.5) Cable soil Zone 4 to 6 (KP 93 to KP 95 to 95.5 (HDD alignment 1), KP 95.5 to KP 96 (HDD alignment 2) ■ Gas expulsion at seafloor – unmapped	3	C	C	■ May cause trenching issues during cable installation ■ Potential for gas kicks and blow out during operations ■ Cable installation and/or removal that may cause pressure changes within the soil may lead to dissociation of dissolved gas. Dissociation may alter geotechnical properties of soil ■ Potential loss of strength of sediments ■ Gas blanking on seismic data leading to less confidence in interpretations	■ Precise depth and extent of shallow gas accumulations ■ Frequency and severity of gas expulsion at seafloor

Pockmarks	Seafloor	Depressions at seafloor caused by gas and/or fluid expulsion processes. Possible link to presence of shallow gas. Possibly caused by dewatering phenomena during sediment compaction	Identified along majority of offshore survey area in cable soil Zones 1a, 2, 3, 4, 5a and 6. Large number identified, particularly abundant in Cable soil Zones 2 and 3	3	D	D	■ Increase in seafloor gradients ■ Potentially related to presence of shallow gas (see shallow gas)	■ Precise cause of pockmarks
Mounds	Seafloor	Mound, or dome-shaped structures identified at seafloor in geophysical data. Regionally associated with mud volcanoes and/or presence of shallow gas/degassing processes	Multiple identified across offshore survey area: ■ Three mounds identified at KP 9.5 across cable soil Zone 1a and 2 ■ Isolated mound at KP 46.5 in cable soil Zone 3 ■ Isolated mound at KP 63.5 to KP 64 in cable soil Zone 2 ■ Cluster of mounds between KP 66.5 and KP 71 in cable soil Zone 2 to 4 ■ Cluster of mounts between KP 74.5 and 76.5 in cable soil Zones 4 and 5a ■ Isolated mound between KP 90 and KP 90.5 in cable soil Zone 4	3	D	B	■ Increase in seafloor gradients ■ Potentially related to presence of shallow gas (see shallow gas)	■ Precise cause of mounds ■ Composition ■ Implications on surrounding soil conditions
High Impedance Reflectors (HIR)	Sub-seafloor	Localised areas of a geophysical horizon with higher amplitudes compared with the adjacent horizon. Interpreted as being related to coarse sediments and/or MDAC	HIR identified extensively in association with Geophysical Horizon H01 and occasionally with Geophysical Horizons H03 and H04. Abundant between KP 7.5 and KP 40 in cable soil Zone 1a, 2 and 3. Present, but less abundant between KP 40.5 and KP 89.5 in cable soil Zones 2, 3, 4, 5a and 5b	2	D	D	■ Variable soil conditions ■ Variable shear strength profiles ■ May require additional engineering consideration for cable trenching and installation	■ Precise cause/composition/geotechnical properties of HIR in subsurface
Escarpment	Seafloor	Geomorphological landform defined as a high, more or less continuous cliff or long steep slope situated between a lower, more gently inclined surface and a higher surface. Regional feature mapped offshore Malta. Potential for areas of exposed bedrock	Cable soil Zone 1a (KP 6.5 and KP 8.0)	3	D	D	■ Excessive topographic differences and increased seafloor gradients ■ Possibility of pipeline trenching tools ■ Bedrock at seafloor ■ Potential for geohazards including slope failures, landslides and mass transport in association with escarpment ■ Buried faults may have unknown geotechnical properties	■ Slope stability ■ If formed by fault, present day fault activity
Submarine channels	Seafloor	Geomorphological features identified in geophysical data. Sinuous, channel-like morphology and increase in water depths/slope angles into feature	■ Two channel features identified feeding towards escarpment (see escarpment). Cable soil Zone 1a (KP 5 to KP 7) ■ One subtle channel feature located nearshore Malta, KP 0.5 to KP 2. Appears to follow regional normal fault (Prampolini et al., 2021)	2	D	B	■ Excessive topographic differences ■ Increased seafloor gradients and slope angles ■ Potential for geohazards including slope failures, landslides and mass transport in association with channel features	■ Presence of geohazards within channel features ■ Slope stability on channel flanks
Bedforms	Seafloor	Mobile sediments (sand) at seafloor forming sedimentary features (bedforms). Ripples and megaripples identified in geophysical data	Geotechnical Unit Ia, cable soil Zone 1a (KP 1 to KP 6)	1	D	B	■ Increase in seafloor gradients ■ Possible cable burial and scour around cable and cable exposure	■ Rate of sediment mobility

Environmental features at seafloor	Seafloor	Species including *Posidonia Oceanica*, *Cymodocea* and *Maerl* mapped at seafloor using available geophysical data. *Posidonia Oceanica* and *Cymodocea* – species of seagrass that are highly protected across Europe. Listed in Annex I of the EC Habitats Directive (92/43/EEC) as a feature for which nature conservation sites are designated (https://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm). *Maerl* is a slow growing, calcareous red algae that forms loose accumulations of calcified algae. Can form large banks and reefs. *Maerl* is listed under Annex V of the EC Habitats Directive (92/43/EEC) (https://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm). Where areas of these species are found, they should be treated as protected areas	■ Generally present in areas of shallow water depths ■ *Cymodocea* – cable soil Zone 6 (KP 96.5 to KP 97 (HDD alignment 1) and KP 96 to 97.5 (HDD alignment 2)) and nearshore Italy ■ *Posidonia Oceanica* – cable soil Zone 1a KP 1.5 to KP 2), nearshore Malta and nearshore Italy. Areas of rocky outcrops encrusted with *Posidonia Oceanica* described in both nearshore areas (Fugro 2022b; Fugro, 2023) ■ *Maerl* – cable soil Zone 1a and 1b (KP 1 to KP 8) and nearshore Malta	4	D	D	■ Areas where these species are mapped will need to be avoided if possible – should be treated as protected areas ■ Alternative cable design and installation methods may be required	■ Areas of species unmapped in geophysical data ■ Protection regulations
Unexploded ordnance (UXO)	Seafloor and sub-seafloor	Unexploded munitions and sea mines. Thirty (30) UXO targets (bombs) were identified through the geophysical survey and ROV survey along the offshore survey area. UXO are considered a regional risk. Malta was the focus of many war activities (WWI and WWII). During World War II, the island of Malta and the surrounding shipping lanes supplying it came under heavy and prolonged attack (https://www.maltatoday.com.mt/news/national/83877/gas_pipeline_planners_warned_over_unexploded_ww2_bombs#.Y5iUYnbP2Uk). UXO are therefore possible across the Malta Plateau	■ Twenty-three (23) located in cable soil Zone 1a between KP 6 ad KP 9.5 ■ Seven (7) located in cable soil Zone 2 between KP 9.5 and KP 12	4	D	B	■ May pose obstruction/constraint to cable installation ■ May limit/restrict further site-investigation work	■ Presence and location of unmapped UXO

Geohazard	Presence (Seafloor/Sub-Seafloor)	Description/Characteristics	Distribution across Cable Route	Severity	Likelihood (Offshore Survey Area)	Likelihood (IC2 Cable Route) *	Engineering Implications	Uncertainties
Seafloor wrecks and debris	Seafloor	Shipwrecks, airplane wrecks and anthropic debris at seafloor	■ No shipwrecks identified in geophysical data through the offshore survey area; ■ No known shipwrecks mapped by UKHO wreck database (Section 2.6.3) in offshore survey area. Abundant shipwrecks nearshore Malta and few nearshore Italy. Multiple across Malta Plateau; • ■ Five (5) airplane wrecks identified as part of UXO mapping: • Four located in cable soil Zone 2 between KP 14.5 and KP 15 • • One located in cable soil Zone 3 between KP 46 and KP 46.5 • • ■ 4 anthropic debris items located: • Three located in cable soil Zone 2 between KP 13 and KP 13.5, KP 34 and KP34.5 and KP 64 and KP 64.5 • • One located in cable soil Zone 3 at KP 44.5 •	4	D	B	■ May pose obstruction/constraint to cable installation ■ May limit/restrict further site-investigation work ■ May have archaeological value	■ Presence and location of unmapped wrecks and debris ■ Presence of UXO within airplane wrecks
Cables	Seafloor	Existing telecommunications cable infrastructure installed at seafloor. Regional cables running across the Malta Plateau. Seven (7) as found cables identified in geophysical data across offshore survey area	Seven (7) 'as found' cables cross the IC2 cable route in cable soil Zones 2 and 3 between KP 17.5 and KP 67.5	3	D	D	■ Existing infrastructure may need to be avoided ■ May require additional engineering consideration for cable design and installation ■ May limit/restrict further site-investigation work	■ Extent of cable burial and thickness of any surficial sediments on top of cable
Pipelines	Seafloor	Existing pipeline infrastructure installed at seafloor. Three 'as found' pipelines identified in geophysical data across offshore survey area and nearshore Italy survey area. None identified regionally in public data	■ One incomplete pipeline segment identified in cable soil Zone 1b between KP 2 and KP 2.5. Approximately 800 m east of IC2 cable route ■ Two incomplete pipeline segments identified in nearshore Italy survey area between KP 98 and KP 98.8 (HDD alignment 2)	3	D	B	■ Existing infrastructure may need to be avoided ■ May require additional engineering consideration for cable design and installation ■ May limit/restrict further site-investigation work	■ Presence of unknown, buried pipelines

Geohazard	Presence (Seafloor/Sub-Seafloor)	Description/Characteristics	Distribution across Cable Route	Severity	Likelihood (Offshore Survey Area)	Likelihood (IC2 Cable Route) *	Engineering Implications	Uncertainties
Fishing activity – trawler scars	Seafloor	Scars in seafloor sediments formed through fishing activity (e.g. trawler nets)	• ■ Individual trawler scars mapped across offshore survey area: • cable soil Zone 2 between KP 17.5 and KP 20 • • cable soil Zone 3 between KP 40.5 and KP 42.5 • • cable soil Zone 2 between KP 62.5 and KP 64 • • Nearshore Malta survey area between KP 1 and KP 1.5 • • ■ Area of trawler scars mapped across offshore survey area: • cable soil Zone 2 between KP 23.5 and KP 29.5 • • cable soil Zone 3 between KP 37 and KP 39.5 • • cable soil Zone 2, 4 and 5a between KP 66.5 and KP 75.5 • • cable soil Zone 4, 5a and 5b between KP 76 and KP 78 •	2	D	D	■ If deep enough, trawler scars may represent areas of increased seafloor gradients ■ Potential for variable soil conditions ■ Potential for unidentified fishing gear to be left at seafloor	■ Frequency of fishing activities along the cable route or in the surrounding region
Military area	N/A	Defined military area located offshore Malta, mapped by FISPA (Fugro, 2022b)	IC2 cable route and offshore survey area cross military area in cable soil Zone 1a and 1b between KP 1.5 and KP 6	1	D	D	■ Possible restrictions on installation of cable route	■ Status of the military area ■ Activity within the military area ■ Implications on cable planning and installation
Restricted area	N/A	FISPA mapped nine (9) restricted areas across the Malta Plateau. Two types: ■ Bunkering area ■ Trawling area	IC2 cable route avoids all restricted areas. One trawling area partially present within offshore survey area in cable soil Zone 1a between KP 5.5 and KP 9.5	1	D	B	■ Possible restrictions on installation of cable route	■ Status of the restricted areas ■ Activity within the restricted areas ■ Implications on cable planning and installation

Notes
Seismological hazards not reviewed within this geohazard register. These are reported separately in Section 7.3
* Assessed based on whether each geohazard was found to directly cross or encounter the IC2 cable route
BSF – below seafloor
N/A – not applicable

7.3 Onshore Geohazards

The onshore operation related to the laying of the IC2 cable consists mainly of trenching works:

- In rock or
- In Fill associated with the perimeter road of the landfill

Shallow trenching in rock presents no geohazards as the rock at the coastline where the cable makes landfall is competent. Although flooding could occur.

Excavation in fill or rock along the landfill perimeter may presents stability hazards as the fill is usually loose and does not form stable vertical walls and may require adequate stabilisation.

Considering that the excavation is taking place next toa landfill adequate measures need to be taken to ensure that there are no buried hazardous fill material or possible poisonous or harmful gas or vapour release.

7.4 Seismological Hazard Assessment

7.4.1 General

This section presents the findings of the seismological hazard assessment. This assessment included a review of publicly available data to inform the potential seismological hazards along the IC2 cable route and their implications on the installed interconnector cable.
It should be noted that this assessment did not include detailed studies such as a probabilistic seismic hazard assessment or probabilistic fault displacement hazard assessment.

7.4.2 Regional Seismic Activity

The Malta Plateau and surrounding region is seismically active due to the complex tectonic setting in which it is located, however, seismic events appear to be relatively low frequency and low magnitude.

USGS earthquake records from across the Malta Plateau and surrounding region were downloaded through the USGS Earthquake Catalog. Earthquake records from the past 100 years with a magnitude greater than 2.5 were downloaded and assessed.

Across the wider region, the majority of earthquakes in the past 100 years have occurred on mainland Sicily, to the north of Sicily in the south Tyrrhenian Sea and in the Sicily Channel. The largest earthquake to occur within the past 100 years took place on mainland Sicily in 1968 and measured magnitude 6.07. The most recent earthquake occurred on the 04 December 2022 (as of 09 December 2022).

Forty-one (41) earthquakes have occurred in the past 100 years within 50 km of the IC2 cable route (both offshore and onshore Sicily/Malta) (Figure 71). Sixteen (16) of these occurred offshore on the Malta Plateau. These were all relatively minor earthquakes, measuring between magnitude 2.5 and 4.6. Future events of this magnitude are not likely to cause major damage to cable infrastructure.

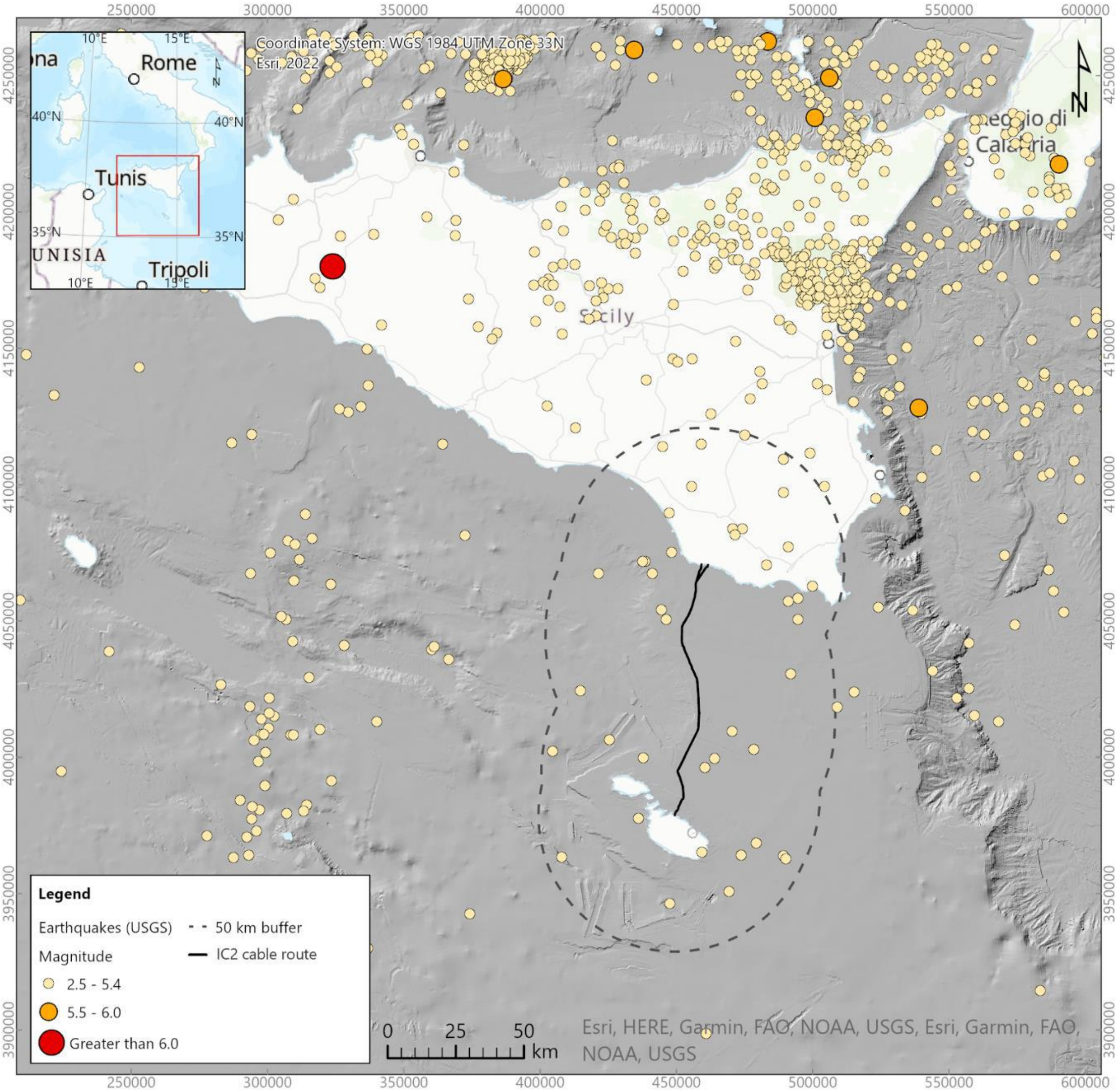


Figure 71: Earthquakes greater than magnitude 2.5 recorded in the past 100 years. Data downloaded from the USGS Earthquake Catalog

7.4.3 Implications on Cable Route

In conclusion, while seismic activity remains low frequency and low magnitude, seismological hazards are considered a risk to the IC2 cable route given the Malta Plateau is seismically active and earthquakes have been recorded across the region. Regional seismic activity may cause several hazards which may affect the cable route, including:

- Direct damage to cable infrastructure if the magnitude of seismic activity is great enough;
- Soil liquefaction and instability of soils surrounding the cable;
- Seismic activity could trigger mass movements (i.e. submarine landslides) on areas of steeper seafloor gradients such as the escarpment identified offshore Malta. Mass movements could bury and/or damage the cable.

Fugro recommended full probabilistic seismic hazard assessment is completed which could determine the ranges of peak ground acceleration that are expected for different return period events.
Slope angles along the cable route are observed to be generally low, meaning that risk of seismic triggered slope instability is not expected to be high across a majority of the route. The escarpment may represent the area of greatest concern with regards to this however, within the survey data no evidence of past slope instability associated with this feature is observed.

No evidence of seafloor displacement associated with fault activity is observed in available data across the IC2 cable route or survey areas. Faults are not mapped in subsurface geotechnical data. Further assessment of possible liquefaction risk will be presented in the “On-bottom strength and sediment instability assessment” (Fugro, 2023, in press).

7.5 The main hazards along the IC2 cable route are:

- Localised shallow/outcropping bedrock (cable soil Zones 1 and 5);
- Very soft fine-grained soils within the depth of interest along most of the cable route;
- A very dense, shallow soil/sand layer in cable soil Zone 3 between KP 36.5 and KP 51.5;
- Shallow gas. Evidence for shallow gas includes abundant pockmarks at seafloor, blanking, gas fronts and gas expulsion at seafloor observed in SBP data. Evidence for shallow gas in cable soil Zone 1, Zone 2, Zone 3, Zone 4 and Zone 6;
- High impedance reflectors. Possibly represent coarse sediments and/or methane derived authigenic carbonate;
- An escarpment and associated channel features at seafloor in cable soil Zone 1a, between KP 5 and KP 8;
- Environmental features which should be avoided; species include *Posidonia Oceanica* (cable soil Zone 1a, nearshore Malta and nearshore Italy), *Cymodocea* (cable soil Zone 6 and nearshore Italy) and *Maerl* (cable soil Zone 1a, Zone 1b and nearshore Malta);
- Anthropogenic hazards/constraints including UXO, existing pipeline and cable infrastructure and military/restricted areas. Anthropogenic hazards/constraints are distributed across cable soil Zone 1 to Zone 5.
- The IC2 cable route is situated in a complex tectonic setting. Publicly available earthquake records and literature were used to assess the seismological hazards risk. The Malta Plateau is seismically active, however seismic events appear to be relatively low frequency and low magnitude. Potential still exists however for damage to cable infrastructure, soil liquefaction and mass movements if larger events were to occur;

- The IC2 cable route used within this assessment was optimised by FUGRO following interpretation of geophysical data, however, 3 further route-optimisation recommendations have been made to avoid outcropping bedrock and areas of blocks at seafloor.

8.0 Potential Impacts And Risks

8.1 Impacts and Risks- Marine Segment of the Cable Route

Potential impact may be due to the establishment of a transition joint pit which must remain accessible during operation. The proposed trenchless methodologies at Il-Ghallis coastline, where the cable makes landfall, shall introduce drilling fluids that have the potential to be absorbed by the ground in porous materials such as porous and fractured rocks of lower Coralline Limestone know to be the rock through which the HDD hole shall be drilled. Ground investigation at landfall has shown that the rock contains layers of highly fracture rock.

Rock cuttings are produced during drilling which may alter the seabed morphology until they are dispersed by wave or current action.

For efficient hole drilling, drilling fluids usually include as a minimum a bentonite-water mixture. Bentonite is a clay mineral and is liable to disperse on the sea bed along fissures that connect the HDD hole being drilled to the seabed. Considering that Bentonite is a clay, dispersal may occur over a wide area. Dispersal may be exacerbated by wave action which may easily enhance dispersal over a wider area.

Plugging of fissures may be required using solid material dispersed in the drilling fluid and injected into the hole during the drilling operations.

The drilling operations may not be straight forward. They may be hampered by damage to the drilling equipment or by heavy storms. Sometimes holes have to be abandoned due to loss of drilling equipment in the drill hole when attempts to recover the equipment fail.

Landslides: It is recalled that the seabed along the offshore cable route consists of rocky coastline with coarse sand and boulders and fine sediments consisting of fine sand silt and clay in the deeper segments.

Laying of the cable may Cause landslides or boulder destabilization along the margin of the deep shore platform identified in the nearshore segment and in the offshore up to the 95m isobath.

Seismic Activity. Trenching of the seabed and burial of the cable will produce a corridor of disturbed seabed sediments which shall be even more prone to disturbance by seismic activity. The earthquake study undertaken did not exclude the occurrence of major earth tremors which may cause sediment liquefaction accompanied by sinking of the cable with serious consequence.

Slope angles along the cable route are observed to be generally low, meaning that risk of seismic triggered slope instability is not expected to be high across a majority of the route. The escarpment may represent the area of greatest concern with regards to this however, within the survey data no evidence of past slope instability associated with this feature is observed.

Direct damage to cable infrastructure if the magnitude of seismic activity is great enough may be accompanied by:

- Soil liquefaction and instability of soils surrounding the cable;
- Seismic activity could trigger mass movements (i.e. submarine landslides) on areas of steeper seafloor gradients such as the escarpment identified offshore Malta.
- Mass movements could bury and/or damage the cable.

Illegal activities such as Bottom trawling may cause seabed sediment disturbance which shall be more serious along the cable route where the seabed sediment has been disturbed by trenching. Bottom trawling is a fishing practice that herds and captures the target species, like ground fish or crabs, by towing a net along the ocean floor.

Anchoring of marine crafts may unknowingly lift the cable off the seabed, causing a major disaster which may be accompanied by seabed disturbance and sediment dispersal possible along a long tract of the cable.

In the deeper seabed covered by soft sediments the laying of the cable will cause dispersal of fine sediments along the major part of the cable route.

Gas Bubbles. Seabed disturbance during trenching may also trigger gas bubbles which may contribute to the fine sediment dispersal. Gas bubbles have been noted during the marine survey. Fine sediments take a long time to settle and will be dispersed over a large area in the presence seabed currents.

8.2 Onshore Segment of the Cable Route

Trenching is often accompanied by noise and dust. This s particularly the case when trenching is done along made ground which covers the major part of the perimeter road of the landfill. Excavated material may be carried away by run off if undertaken during the rainy season with negative impacts on the coastal waters.

Trenching along the initial segment of the route out of the landfill shall be on pristine limestone pavement with negative impacts on geology and geomorphology.

8.3 Mitigation

The proposed trenchless methodologies at Il-Ghallis coastline, where the cable makes landfall, shall reduce impact of the cable at landfall.

The onshore trench is narrow and shall mostly be cut in fill material.

Considering the data collected during the marine nearshore and offshore surveys, the off shore cable route shall be chosen so as to avoid:

- Boulders
- Channels
- And other hazardous obstacles.

The earthquakes that occur from time to time on the Malta Sicily Platform are low intensity ones associated with tension (normal) faults and therefore sediment liquefaction and/or landslides are unlikely. They have never been recorded.

Impact Type and Source			Impact Receptor		Effect and Scale											
Impact type	Specific intervention leading to impact	Project phase	Receptor type	Sensitivity & resilience towards impact	Direct/ indirect/ cumulative	Beneficial/ adverse	Severity	Physical/ geographic extent of impact	Short/ medium/ long term	Temporary/ permanent	Reversible/ irreversible	Probability of impact occurring (inevitable/ likely/ unlikely/ remote/ uncertain)	Overall impact significance	Proposed mitigation measures	Residual impact significance	Other requirements
Sea water contamination	HDD Drilling Fluid	Construction	Seawater	High	Direct	Adverse	High	Nearshore	Short term	Temporary	Irreversible	Likely	Minor	Mitigation measures to limit the leakage potential during the drilling of the HDD hole include creating bunds with sandbags, underwater screens and additives to plug holes in voids.	Minor	None
Seabed Sediment dispersal	Trenching on the seabed	Construction	Marine environment	High	Direct	Adverse	High	Local	Short term	Temporary	Reversible	Likely	Minor	Adopt trenching methodology with the lowest seabed disturbance	Minor	None
Seabed Sediment dispersal and cable damage	Anchoring of marine crafts that may uplift the cable and cause sediment dispersal	Operation	Marine environment	High	Direct	Adverse	High	Local	Short term	Temporary	Reversible	remote	Not Significant	Clearly document cable route	Not significant	Creating a geo-reference of the cable on GPS navigation systems of vessels may be considered. This would help limit physical damage

Impact Type and Source			Impact Receptor		Effect and Scale											
																to the cable by heavy anchoring and/or trawling as well as the associated environmental repercussions.
Seabed Sediment dispersal	Strong earthquakes	Operation	Marine environment	High	indirect	Adverse	High	Local	Short term	Tempor ary	Reversible	Unlikely	Not Signific ant	None	Not Significant	None
Seabed Sediment dispersal	landslides	Operation	Marine environment	High	indirect	Adverse	High	Local	Short term	Tempor ary	Reversible	Remote	Not Signific ant	None	Not Significant	None
Landslides	Laying of cable	Construction	Marine environment	High	Direct	Adverse	High	Local	Short term	Tempor ary	Reversible	Remote	Not Signific ant	None	Not Significant	None
Landslides due to earthquakes	Earthquakes	Operation	Marine environment	High	indirect	Adverse	High	Local	Short term	Tempor ary	Irreversible	Remote	Not Signific ant	None	Not Significant	None
Seabed sediment liquefaction	Earthquakes	Operation	Marine environment	High	Indirect	Adverse	High	Local	Short term	Tempor ary	Irreversible	Unlikely	Not Signific ant	None	Not Significant	None
Release of gas bubbles and seabed sediment disturbance	Trenching operations	Construction	Marine environment	High	Direct	Adverse	High	Local	Short term	Tempor ary	Irreversible	Likely	Minor	None	Not Significant	None
Dust release	Trenching operations	Construction	Onshore environment	Moderate	Direct	Adverse	mod erate	Depends on wind and wind direction	Short term	Tempor ary	Reversible	Likely	Minor	None	Not Significant	None
Geology-Removal of rock strata	Trenching operations	Construction	Onshore and offshore environment	Low	Direct	Adverse	low	Local	long term	Perman ent	Irreversible	Likely	Minor	None	Minor: Rock strata once removed can never be replaced but	None

Impact Type and Source			Impact Receptor		Effect and Scale											
															the trench is narrow	
Degradation of the Geomorphology	Trenching operations	Construction	Onshore and offshore environment	Low	Direct	Adverse	low	Local	long term	Permanent	Irreversible	Likely	Minor	None	Minor: Rock strata once removed can never be replaced	None
Production of waste stone material	Trenching operations	Construction	Onshore and offshore environment	Low	Direct	Adverse	low	Local	long term	Permanent	Irreversible	Likely	Minor	None	Minor: most of the onshore waste stone material will originate from the perimeter road mostly made up of fill material which could be reused (if uncontaminated and of the right thermal properties) to backfill the trench to bury the Interconnector cable. The same occurs with the offshore segment in soft sediment where laying of the cable is accompanied by burial.	None

9.0 Residual Impacts

9.1 Onshore Residual Impacts

The onshore segment of the Interconnector is a trench to be cut mostly in fill, along the perimeter road of the Maghtab Ghallis Landfill. The only residual impact of any concern is the segment cut at the Joint Bay where the cable makes landfall.

Geological strata once removed can never be replaced. Likewise, any geomorphological features, in this case, the limestone pavement once disturbed can never be restored considering that rock strata take millions of years to be deposited and consolidated.

9.2 Offshore residual impacts

Geological strata once removed can never be replaced. Likewise, any geomorphological features, in this case, the seabed sediments once disturbed can never be restored considering that sedimentary strata may take millions of years to be deposited and consolidated.

In addition, other residual impacts are related to sediment dispersal:

- Sediment dispersal takes place through gas release from the underlying sediments
- Seabed currents may disperse reworked sediments generated during the laying of the interconnector cable
- Bottom trawling-Dragging of any fishing tools on the seabed by trawlers will cause sediment dispersal with potential damage to the interconnector cable.

9.3 Mitigation Measures

Onshore Mitigation Measures

The width of the trench required to bury the electrical interconnector cable is narrow as the diameter of the cable is not more than 20cm so that the disturbance of pristine terrain is small. Moreover, most of the cable will be buried in the landfill perimeter road where the geology and geomorphology have already been disturbed beyond repair.

Offshore Mitigation Measures

Most of the cable lies in water depths which are normally beyond the reach of anthropogenic interference. Establishing a corridor where no seabed trawling or dredging and deep diving is prohibited will eliminate potential disturbance of the sediments which shall be disturbed during burial of the cable.

Potential disturbance by storm weather conditions is also mitigated as the shallow segment of the cable route at il-Ghallis coastline lies on rocky seabed. The deeper segment will not be affected as the depth of seabed erosion by storm waves is equivalent to half the wavelength which according to Metocean modelling is not more than 15m (Table S.2: All-Year, 100-year Omni-Directional Wave Criteria in: Metocean Criteria and Sediment Transport for Malta-Italy Cable Route Report Mediterranean Sea F211821 212512_1 R1 25 January 2023). Half this wavelength is 7.5m.

Mitigation measures to limit the leakage potential during the drilling of the HDD hole include creating bunds with sandbags, underwater screens and additives to plug holes in voids.

9.4 Monitoring

Monitoring shall take place in the form of:

- prevention of bottom trawling along the cable route
- Prevention of deep diving on the wrecks and other objects spotted on the seabed along the cable route by SSS and ROV surveys.
- Earthquake monitoring for potential major tremors which may produce sediment liquefaction.

10.0 References-Text Consulted

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[6] UoM_01 AUV SSS survey - University of Malta

[7] 171002-3H-DT-B-6101 Melita Transgas Pipeline Hydrogen Ready Pipeline - Offshore Pipeline General Route and Profile

3.2 Project Documents
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[11] CT301322_IC2_GEN_OTH_105 Existing cable crossing assessment report

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