ALLEGATO 16.3

Bathymetric and geophysical survey in the port of Taranto

ANNEX 1: BATHYMETRIC AND GEOPHYSICAL SURVEY IN THE PORT OF TARANTO (ITALY)

G E N E R A L   C O N T E N T S

PART 1. BATHYMETRIC SURVEY

INDEX

FIGURES

1. INTRODUCTION

In November 2004, Alatec S.A. was charged by Gas Natural to develop the project of the new LNG Terminal in the Port of Taranto (Italy).

In order to accurately know the depths and morphologic characteristics of the land where the terminal of regasification and areas of the marine access will be located, the development of the project includes the bathymetric and geophysical survey investigation that is object of this annex.

This document describes the hydrographic survey done and the equipments and methods used.

2. GEOGRAPHICAL LOCATION

The area of study is located in the Gulf of Taranto (Port of Taranto, Italy).

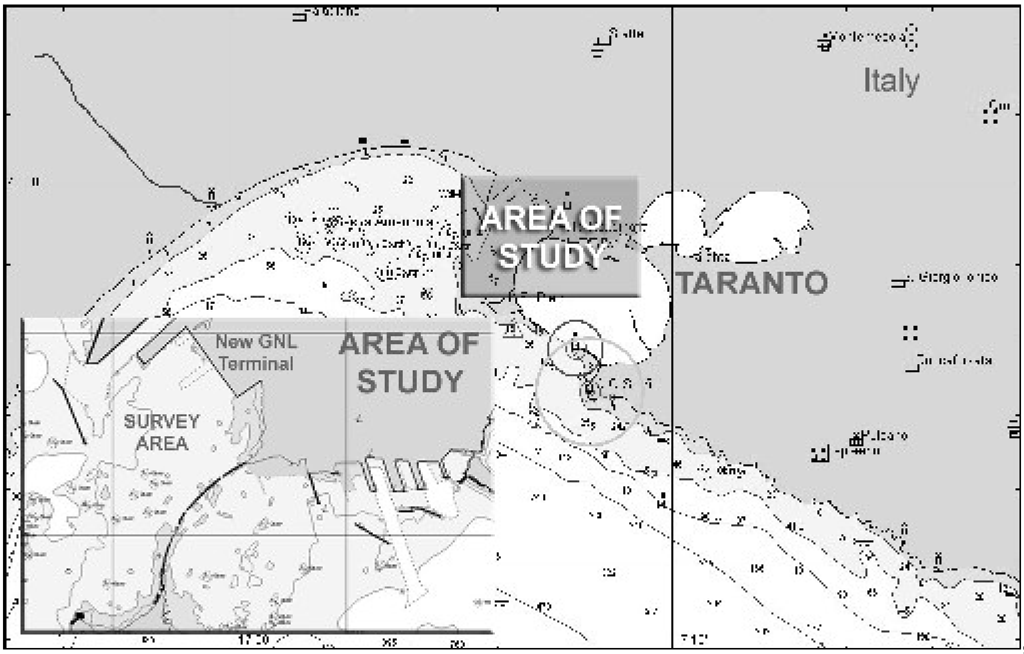

figure 1- Geographical location of the area of study

3. TOPOGRAPIC REFERENCE

The cartography issued by the Italian Geographic Institute (IGM) was used as base map. The vertical reference was set by base IGM95 202701 493 sez 0 and referred to the mean sea level as defined by the IGM (Istituto Geografico Militare).

For a correct leveling of the tide measurements, a topographic base was set at the dock where the gauge was installed. A *Topcon Hiper* GPS was used for that purpose.

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figure 2- Topcon Hiper GPS-GLONASS

4. BATHYMETRIC SURVEY

4.1 Planning

The hydrographic software package *Hypack Max* was used for the acquisition and postprocessing of the data. This program allows navigation line planning and data acquisition during the survey of the single beam echosounder, GPS and motion sensor.

A total number of 41 lines (81 km) were planned for the bathymetric survey. The lines were drawn along and across the main axis of the surveyed area.

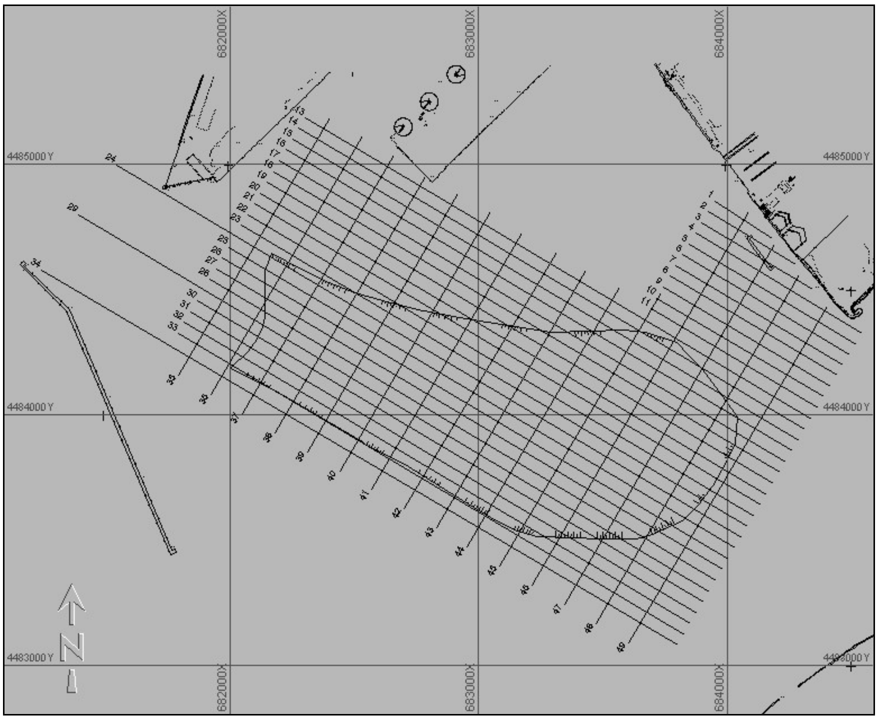

figure 3- Planned navigation lines for Taranto

4.2 Data acquisition

The bathymetric survey was done the 22nd and 23rd of November 2004. Due to excellent weather conditions, no stand-by was forced due to climatology.

The survey boat used was *Kyry IV*, launched by *Sommozzatori Soc. Coop. a R.L*

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figure 4-* Survey boat *Kyry IV

4.2.1.Hydrographic equipment

A series of hydrographic equipment was used to complete the survey.

4.2.1.1.Tide gauge

A *Valeport 740* precision tide gauge was installed in the "Canale Navigabile di Zaule" to get an accurate record of sea level changes due to tides during the survey. With the resulting tidal record, the link between each sounding and the horizontal origin can be done.

The *Valeport 740* tide gauge has a precise pressure sensor and is vented to the surface, therefore it is not necessary to correct atmospheric pressure.

The tide gauge was calibrated on site and set to a burst cycle of 10 minutes with a burst length of 60 seconds.

The pressure sensor is always located below the hydrographic zero and also referred to a levelled topographic base located at the edge of the dock.

figure 5- *Valeport 740* tide gauge

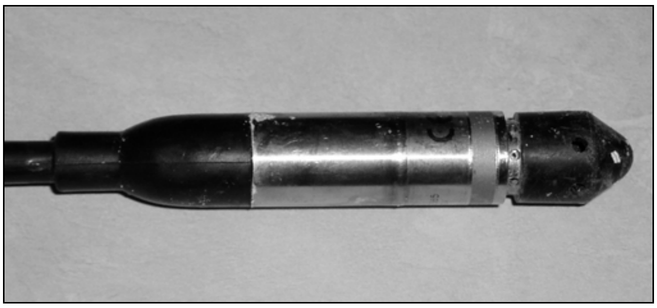


figure 6- Pressure sensor of the *Valeport 740* tide gauge

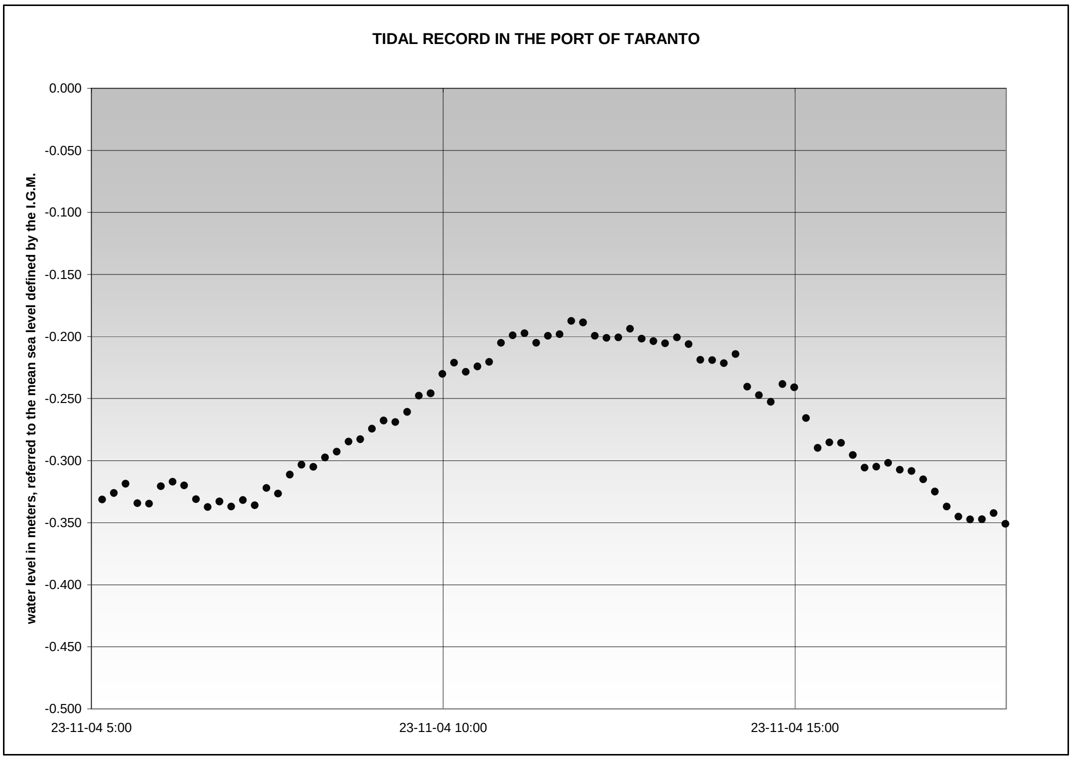


figure 7- Tidal record of the survey (height in meters and time in Coordinated Universal Time)

4.2.1.2.Single Beam Echosounder

The bathymetric survey was done with a *Elac Hydrostar 4300* double frequency hydrographic echosounder.

The sound velocity in the water column was calibrated on site according to the salinity and temperature conditions. The sound velocity was measured with a *Navitronik SVP15* sound velocity probe. The obtained value was 1505 m/s.

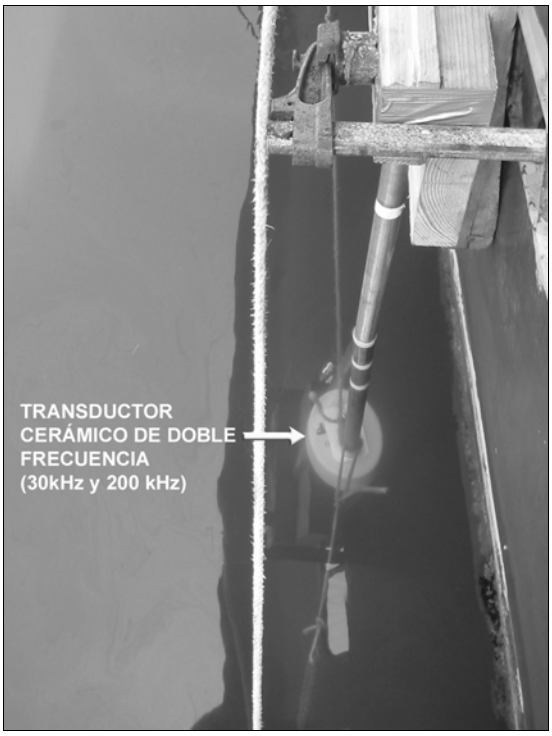


figure 8- Double frequency ceramic transducer

figure 9- Single beam transceiver and navigation/acquisition computer

4.2.1.3.Global Positional System with differential corrections (dGPS)

The dGPS locates the transducer in the three dimensional space, allowing horizontal submetric precision for all soundings.

Positions during the survey were obtained using a *Topcon Map-R GD* dGPS and a *csi Wireless CDA-2* antenna receiving *Omnistar* satellite corrections

figure 10- *Topcon Map-R GD* dGPS receiver and *csi Wireless CDA-2* dGPS antenna

Since the base maps were referred to the WGS84 ellipsoid and datum, no corrections were needed for navigation and acquisition.

4.2.1.4.Motion Sensor

In order to record and correct all movements of heave, roll and pitch (HRP) caused by waves and wind a *TSS MAHRS* attitude and reference system was used. The use of a motion sensor allows to survey even in non-ideal conditions of the sea.

figure 11- *TSS MAHRS* motion sensor

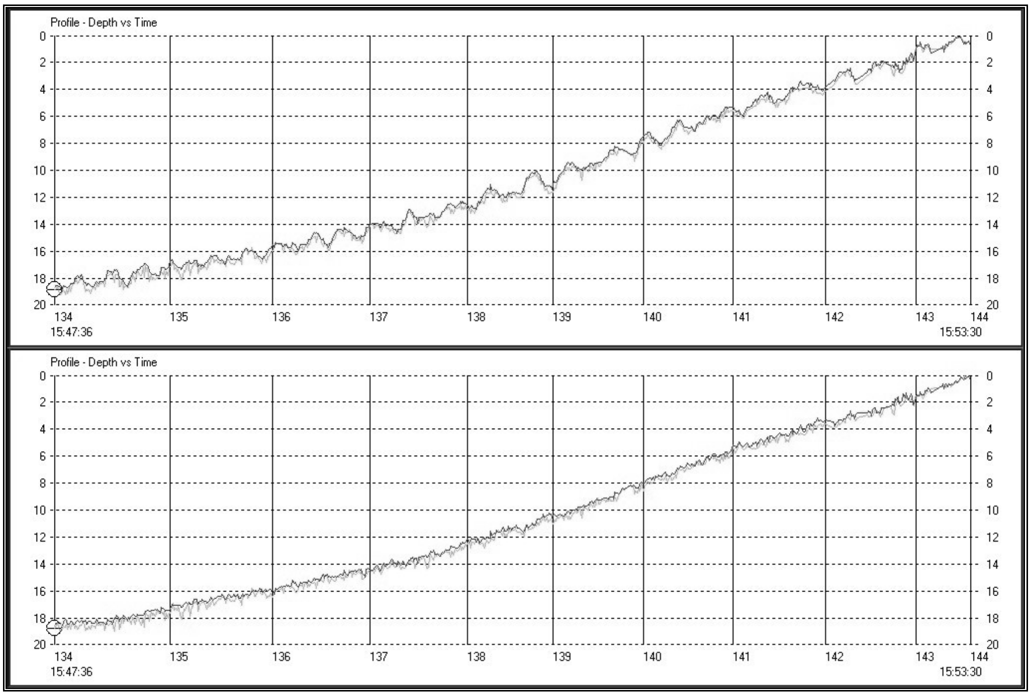


figure 12- Bathymetric profile without applying HRP corrections (upper)

Bathymetric profile applying HRP corrections recorded by the motion sensor (lower)

4.2.2.Data acquisition

Once all equipments are installed and secured, all connections and data quality of each device are checked again.

During the survey, each equipment sends uninterrupted data to the computer. The acquisition software records and stores gross data, which will be processed later on in the office.

4.3 Data postprocessing and isobaths contouring

Once all field data are acquired, data postprocessing in the office takes place. During this process, all errors, failures and wrong signals are cleaned. On the other hand, all soundings are referred to a common origin using the tidal record and the HRP data.

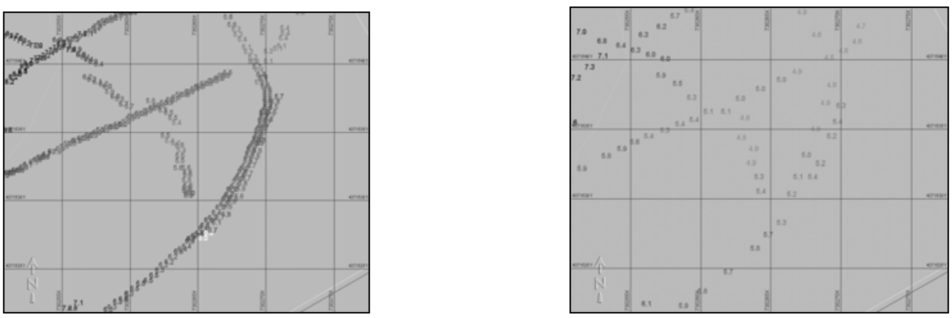


figure 13- Detailed example of gross data (left) and edited soundings at the same location (right)

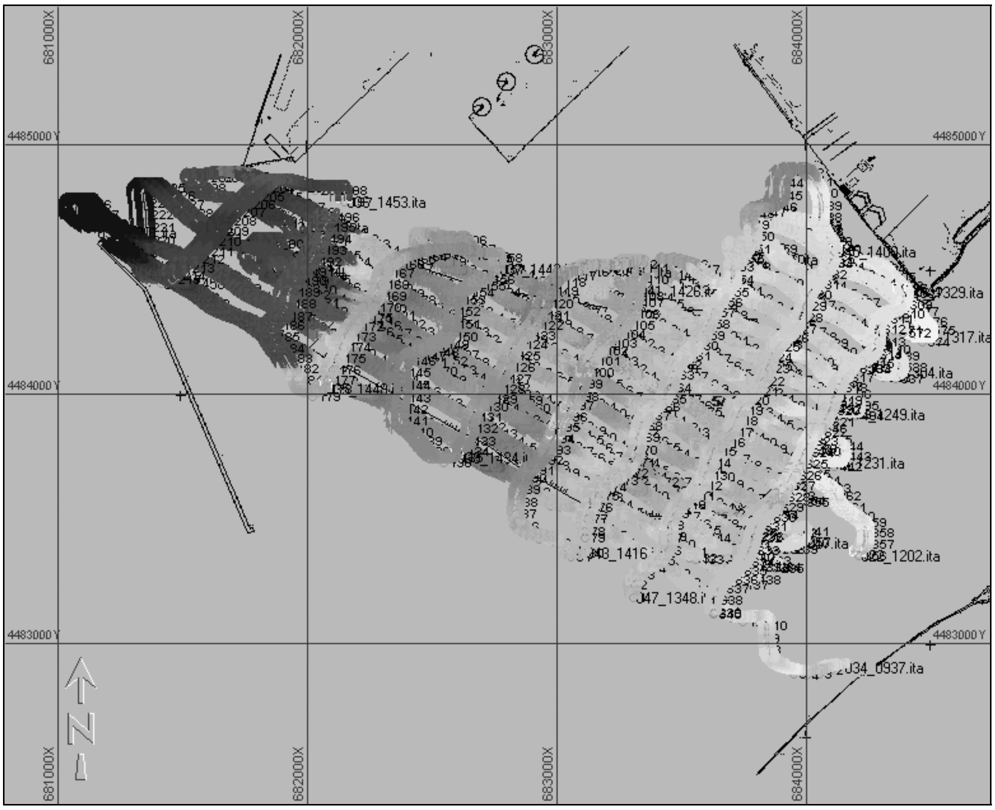


figure 14- General view of gross bathymetric data in Taranto

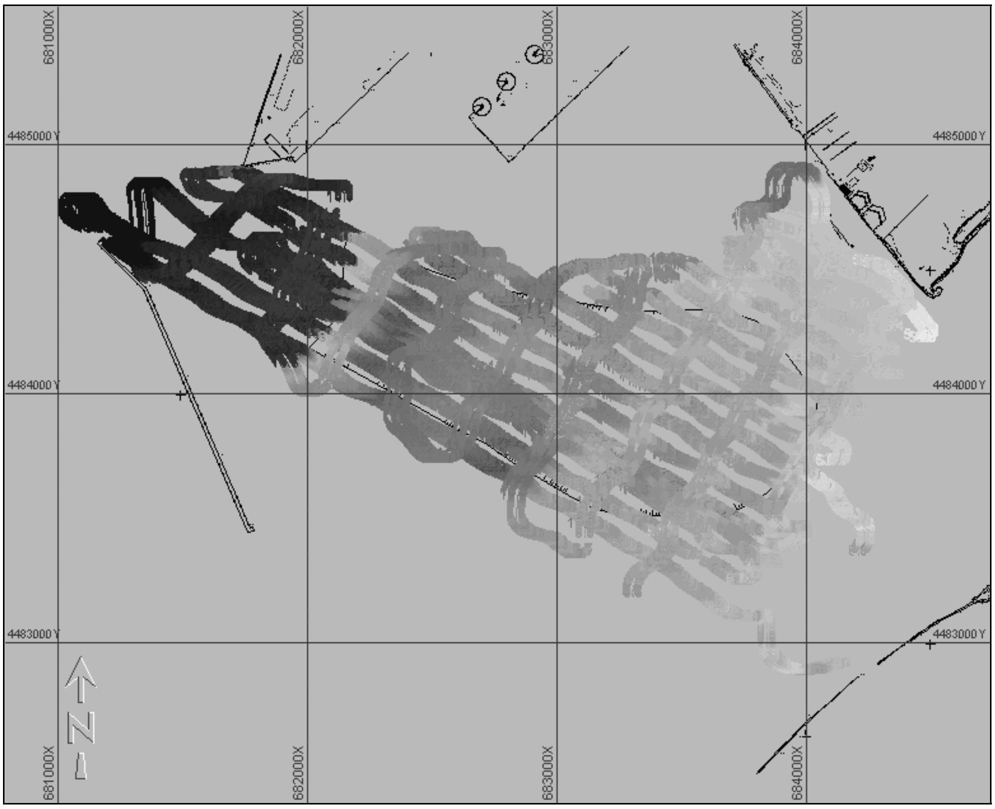
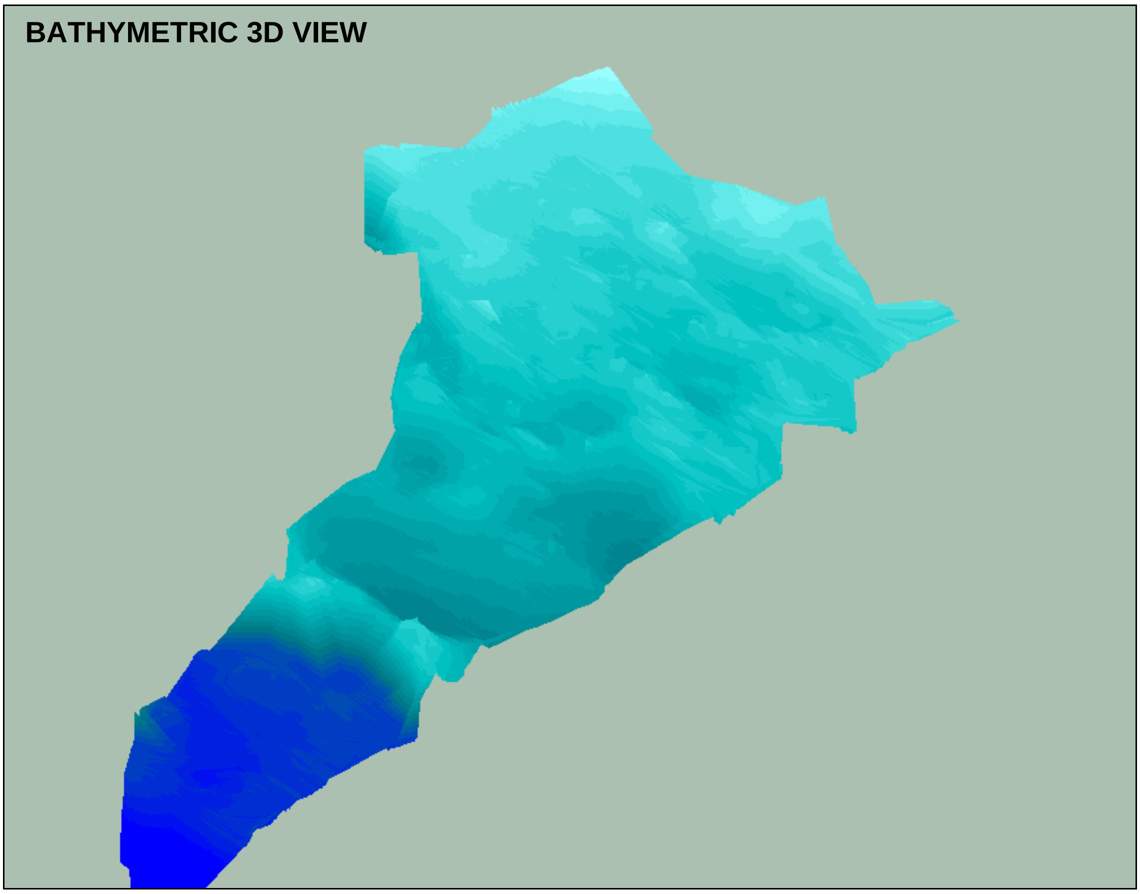


figure 15- General view of edited and corrected soundings in Taranto

5. CARTOGRAPHIC EDITION

Once all bathymetric data are obtained, a mathematical contouring with all soundings was performed using Kriging methods.

In the map 1, all the bathymetric isolines of the surveyed area are shown.



PART 2. GEOPHYSICAL SURVEY

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FIGURES

1. INTRODUCTION

In this part of the annex is described the geophysical survey done in the project location in order to know the rock ceilings and the general characteristics of the marine bottom, whose knowledge is of the most importance for the laying of foundations of the projected structures and, of course, in order to obtain a trustworthy knowledge of the characteristics of the marine bottoms where are to take place the dredged for construction of the waterways and manoeuvring areas for the ship that operate in the terminal.

The cartography issued by the Italian Geographic Institute (IGM) was used as base map. The vertical reference was set by base IGM95 202701 493 sez 0 and referred to the mean sea level as defined by the IGM (Istituto Geografico Militare).

For a correct leveling of the tide measurements, a topographic base was set at the dock where the gauge was installed. A *Topcon Hiper* GPS was used for that purpose.

2. GEOPHYSICAL SURVEY

The following actions were undertaken:

- A geophysical study using a Sub-bottom Profiler in order to determine the thickness of non-consolidated sediments and the top limit of the consolidated substratum.
- A geophysical study using a continuous-reflection high-resolution marine seismic system (Boomer-type) in order to assess the amount of non-consolidated sediment in that area, its geological map and the features of the acoustic basement.
- Interpretation of the geophysical results obtained.

2.1 Planning

The hydrographic software package *Hypack Max* was used for the navigation line planning and guiding during the survey of the geophysical survey.

A total number of 41 lines (81 km) were planned for the bathymetric survey. The lines were drawn along and across the main axis of the surveyed area.

Control of navigation and positioning of all data throughout the hydrographical campaign is made based on the positioning the dGPS unit. This unit is connected to a suitable computer package to make the correct acquisition of all digital data on the seismic results registered by the *SonarWiz SBP* computer package, made by *Chesapeake*.

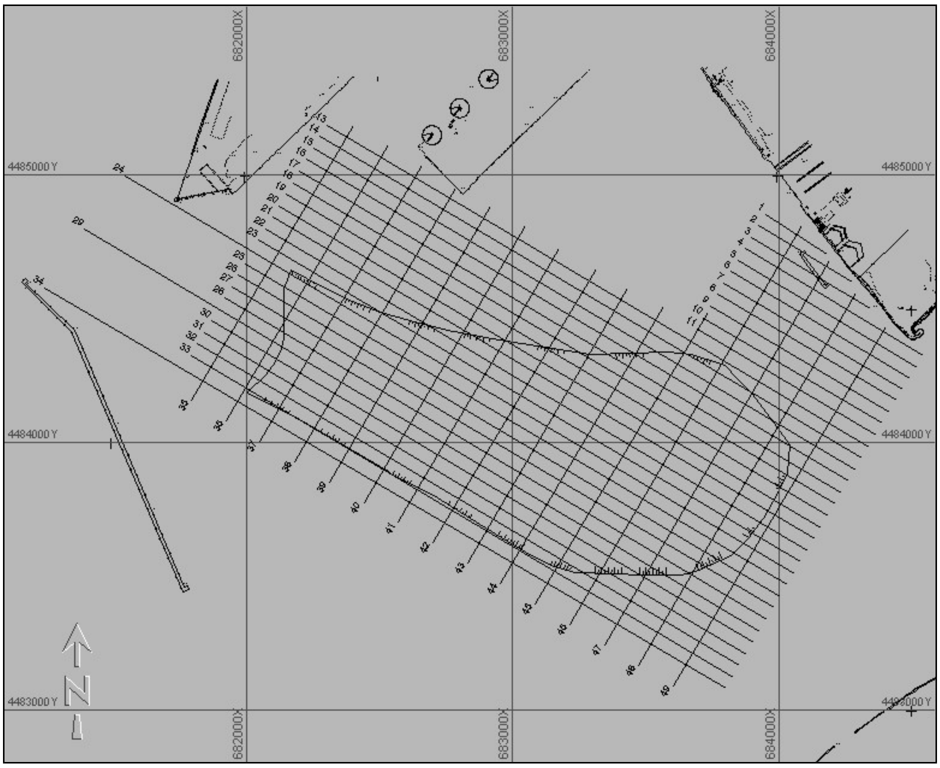

figure 1- Planned navigation lines for Taranto

2.2 Data acquisition

The geophysical survey was done the 22nd and 23rd of November 2004. Due to excellent weather conditions, no stand-by was forced due to climatology.

The survey boat used was *Kyry IV*, launched by *Sommozzatori Soc. Coop. a R.L.*

figure 2- Survey boat *Kyry IV*

2.2.1.Methodology

Research carried out was based on seismic profiles obtained through the *ORE 3.5* continuous-reflection high-resolution Seismic Profiler, as well as a marine seismic system and the *Geoacoustics Geopulse* continuous-reflection high-resolution marine seismic system.

Those geophysical principles applied to continuous-reflection seismics in underwater research are based on the production of an acoustic impulse with specific features by an emitting source. Initially, the frequency spectrum of an acoustic emitter is variable and shows a wide frequency range.

The high frequencies are absorbed more quickly than the low ones, which can travel farther. However, depending on the amount of energy absorbed, there is an inverse relation between resolution and penetration, where the higher-penetration systems are those with the lowest levels of resolution and vice versa. Wave fronts spread in all directions and the energy is partly reflected and partly refracted every time the physical conditions change.

The main parameter for any geophysical interpretation in the marine environment is Acoustic Impedance. The acoustic impedance (Z) of sediment is determined by the production of the velocity of a compressional wave (C) in that environment, and its total density (ρ).

$$Z = C \cdot \rho$$

Reflection intensity basically depends on the contrast regarding acoustic impedance between the layers of sediment on the sub-bottom and the marine substratum.

Propagation velocity in acoustic waves on the earth's crust ranges from some 6,000 to

7,000 m/s in igneous rocks and 1600 to 1750 m/s in non-consolidated superficial sediment (mud and sand).

The reflection originated both in the water-sediment interphase and between several sedimentary units provides us further knowledge about the depths of the marine sub-bottom and about each interphase, based on the time lapse between emission and reception of the reflected wave. This lapse is known as Double Time (DT) and is expressed in milliseconds (ms). The depth of a reflector is calculated by using the following formula:

$$P = \frac{V \cdot T}{2}$$

Where V represents the speed of sound, which is 1500 m/s for sea water, and from

1600 m/s to 1800 m/s for non-consolidated superficial sediment.

Certain factors diminish the reflection intensity of acoustic waves, such as: roughness in interphases, distance and angle in relation to the emitting source, its power and sound refraction in stratified water.

Another relevant factor regarding the level of penetration is obviously the composition and nature of the sediments on the sub-bottom and marine substratum. Most of them work as reflectors or deflectors of acoustic energy.

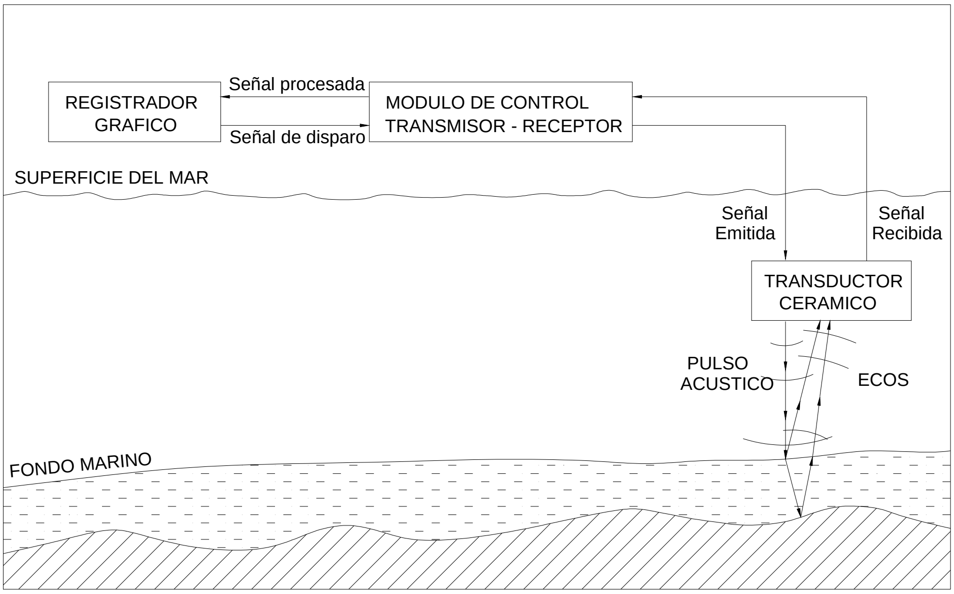

figure 3- Performance of a 3.5 kHz Sub-bottom Profiler system.

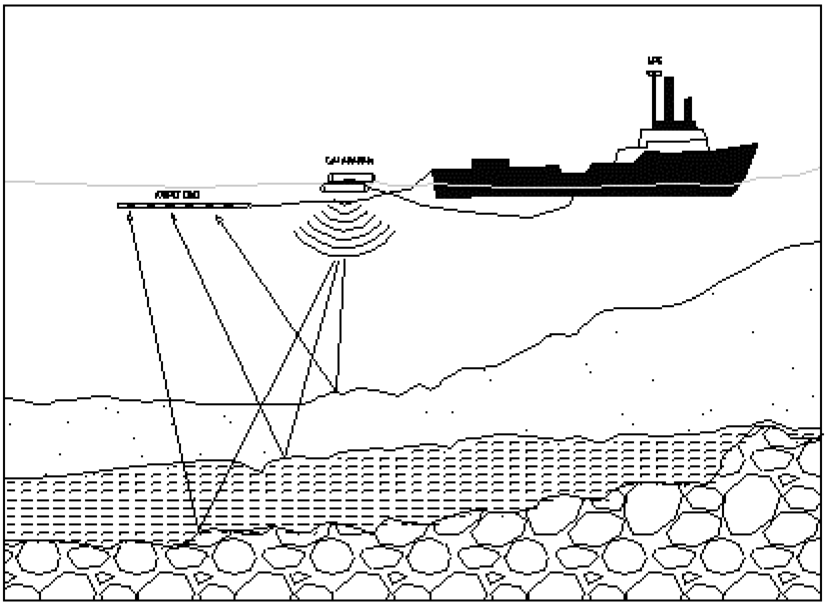

figure 4- Performance of a Geopulse system

2.2.2. Hydrographic equipment

A series of hydrographic equipment was used to complete the survey.

2.2.2.1. 3.5 kHz Sub-bottom Profiler

In order to undertake this study, a continuous-reflection high-resolution system, working at a 3.5 kHz frequency (which is ideal to determine the geological map of non-consolidated sediments such as mud and sand) was used.

figure 5- Sub-bottom profile transmitter-receiver unit

It is a seismic system featuring medium penetration levels (30 - 40 m) and high resolution (0.2 m). The emission pulse is 10 kW and frequency is adjustable from 3 to 11 kHz.

The system provides a continuous registry of the sub-bottom and the marine substratum through the *Sonarwiz SBP* data acquisition software, by *Chesapeak*, which is also registered on an *EPC 1086* thermal printer. The results show the geological map of the substratum based on the presence of layers of mud, sand, rock, etc., as well as other elements to measure the depth at which they are inter-stratified under the bottom.

The system is comprised of the following subsystems:

- Reception and filtering unit. Energy and pulse/signal control unit.
- Condensers which produce high-voltage currents in 0.2 ms.
- Acoustic source: ceramic transducers produce acoustic pulse and lead to the transmission of the pressure wave through a water column which is able to penetrate non-consolidated marine substratum.
- PC with *Sonarwiz SBP* software featuring two simultaneous input channels. It controls the registry and programmes dealing with pulse emission, cadence and reception scan.
- EPC 1086 high-resolution seismic register: it is an analogical precision register on thermal paper.

The seismic results obtained have been recorded on the *Sonarwiz SBP* computer package featuring positioning, as well as a dry-paper thermal analogical register with a cadence of ¼ seconds (250 ms) and a scan of 116 ms.

Fixes have been marked every 50 metres, and will then be matched to the itineraries of the ship's tracks, as well as the beginning and the end of each line.

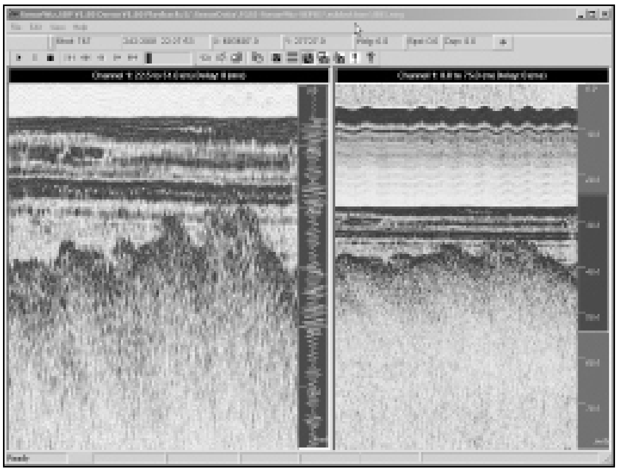

figure 6- Screen of the Data Acquisition Software

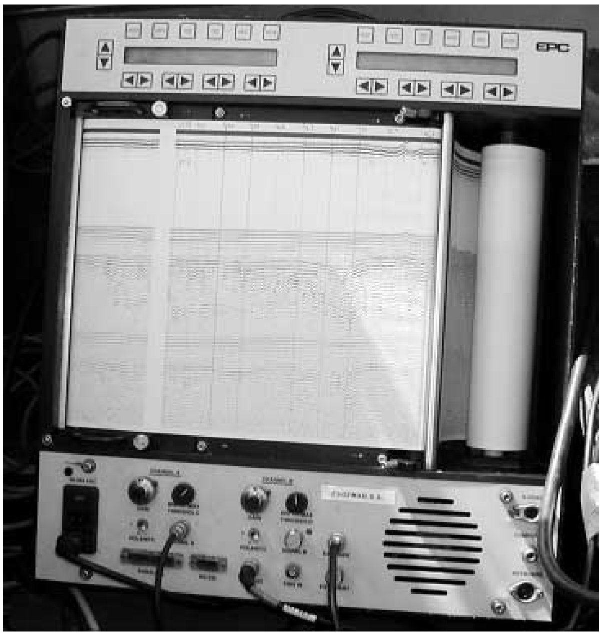

figure 7- EPC graphic register on thermal paper

figure 8- Ceramic transducers located on the ship's portside

2.2.2.2.Geopulse seismics

The *Geoacoustics Geopulse* continuous high-resolution reflection system was used to carry out the survey.

It is a seismic system featuring medium penetration (30-100 m) and high resolution

(0.3 - 0.4 m). The energy of emission pulse ranges from 75 J and 405 J, and frequency goes from 200 Hz to 2000 Hz.

Alike Sub-bottom Profilers, the seismic results obtained have been recorded on the *Sonarwiz SBP* computer package featuring positioning, as well as on an EPC 1086 dry-paper thermal analogical register with a cadence of ¼ seconds (250 ms) and a scan of 116 ms.

Fixes have been marked every 50 metres, and will then be matched to the itineraries of the ship's tracks, as well as the beginning and the end of each line.

The Geopulse seismic system is comprised of the following subsystems:

- Reception and filtering unit.
- Energy bank: a group of condensers which can produce high-voltage currents in

  0.2 ms.
- Acoustic source: it produces electric pulse and creates wave transmission through the entire water column.

- Receiver or streamer (hydrophone): it receives reflected waves and is formed by a series of hydrophones and an amplifier.
- PC with Sonarwiz.SBP software featuring two simultaneous input channels.
- EPC 1086 register: it is a dry-paper analogical precise register. Is controls registry on paper, as well as the pulse emission programmes and its cadence and scan.

figure 9- Geopulse system

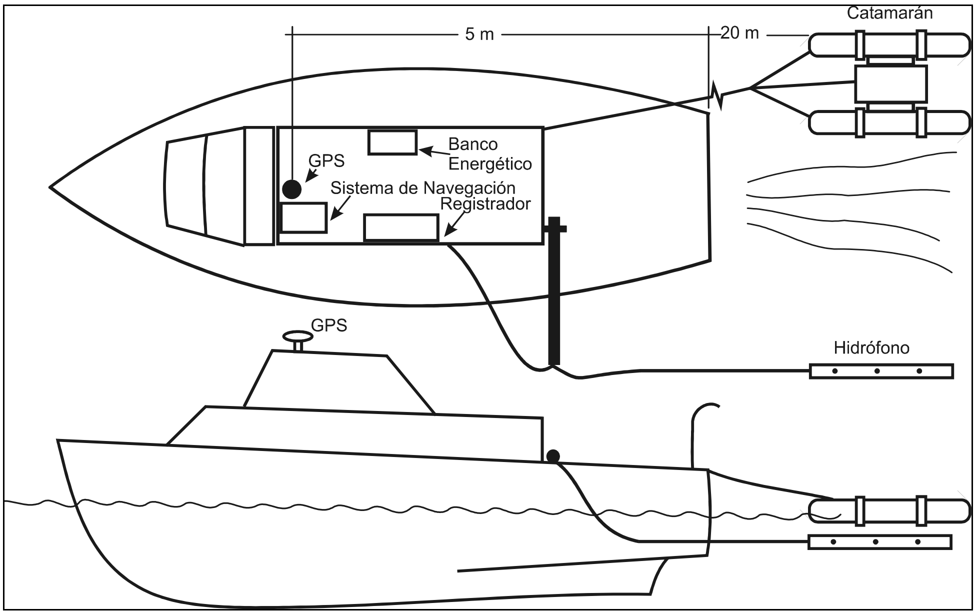

figure 10- Onboard display of theGeopulse seismic survey system throughout continuous-reflection seismic research.

2.2.2.3.Global Positional System with differential corrections (dGPS)

The dGPS locates the transducer or the hydrophones in the three dimensional space.

Positions during the survey were obtained using a *Topcon Map-R GD* dGPS and a *csi Wireless CDA-2* antenna receiving *Omnistar* satellite corrections

figure 11- *Topcon Map-R GD* dGPS receiver and *csi Wireless CDA-2* dGPS antenna

Since the base maps were referred to the WGS84 ellipsoid and datum, no corrections were needed for navigation and acquisition.

Afterwards, data recorded on a digital copy on *Sonarwiz SBP* software, as well as data registered on the *EPC 1086* graphic printer, were processed while making the instrumental corrections related to velocity of acoustic propagation, layback, etc, thus obtaining the plotting of itineraries made together with fixes.

2.2.3.Data acquisition

Once all equipments are installed and secured, all connections and data quality of each device are checked again.

During the survey, each equipment sends uninterrupted data to the computer. The acquisition software records and stores gross data, which will be processed later on in the office.

2.3 Data postprocessing and isopaches contouring

Once the seismic data had been placed on a digital copy, the curb of the thickness isolines for the sedimentary units chosen was made, creating isopaches which were then marked on the corresponding maps.

The seismic results obtained have produced the following maps and registry information:

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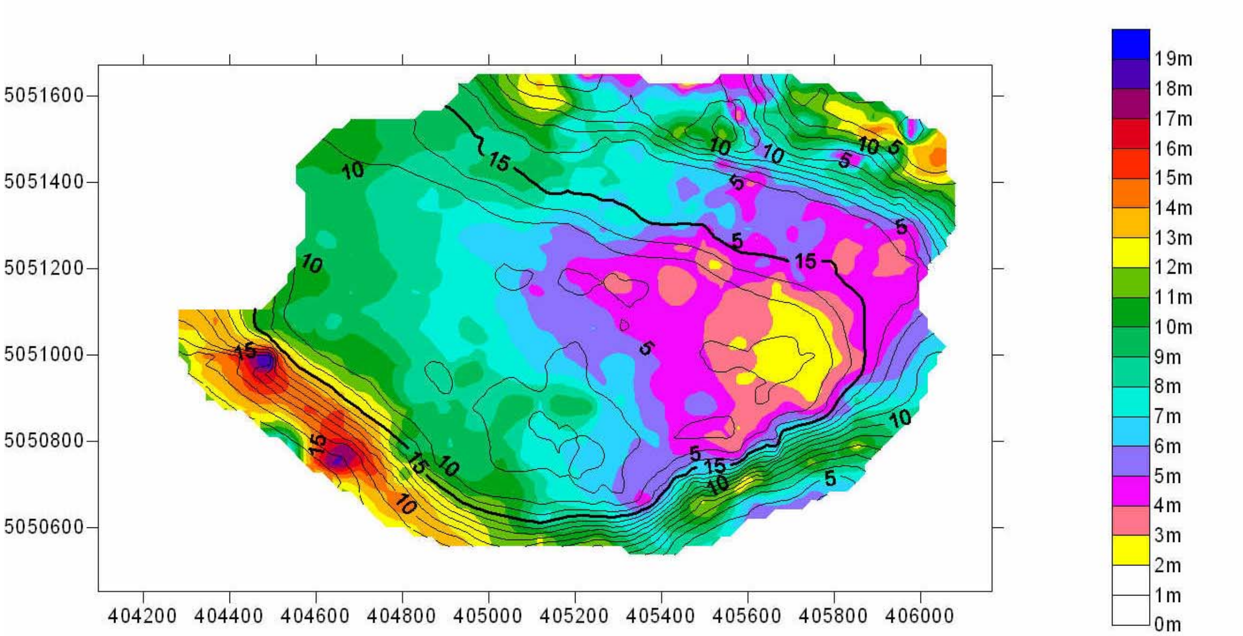


figure 12- Isopaches of the sediment covering in the area under study. Thickness curbs have been marked in colours. Black curbs are a guideline on the bathymetric relief.

3. RESULTS

The results obtained by using these two systems allow establishing the morphological and geological map conditions of the marine sub-bottom developed in this area.

The resulting map has been made based on the digitalization of the interpretation of the sedimentary thickness registered in continuous-reflection seismic systems (the Profiler and the Geopulse System). A propagation velocity of 1750 m/s has been used for non-consolidated materials.

The general scheme of the subsoil of the investigated zone, is related to sediment deposits non consolidated corresponding to fluvial sequences, of lagoons and sea sequences that fill up paleochannels excavated in a consolidated substrate. The deposited seismic stratigraphy sequence of non consolidated sediments is represented by assimilated materials clays, muds and fine sands and gravel levels, in which it is possible to be distinguished two subunits:

- Very complex superficial subunit constituted by clays, muds, and gravel levels. In this subunit isolated aflorantes structures of greater hardness could be assimilated to “paleo restingas” or fossilized coastal cords.
- Deeper subunit, formed by laminated fine sediments assimilated to fine sands, gravel levels and rest of rock altered in the wall. This subunit is deposited discordant on an irregular erosive surface of consolidated material (paleochannels), of aqueous nature formed by hard clays or cemented marls of laminated structure.

In the lowest limit of the deeper subunit it appears the consolidated substrate, constituted by aqueous rocks of hard clays or laminated marls. The ceiling of this unit is defined by an erosion surface that forms paleochannels of one old fluvial network that ended at the sea.

The isopaches maps obtained show thickness in metres as follows:

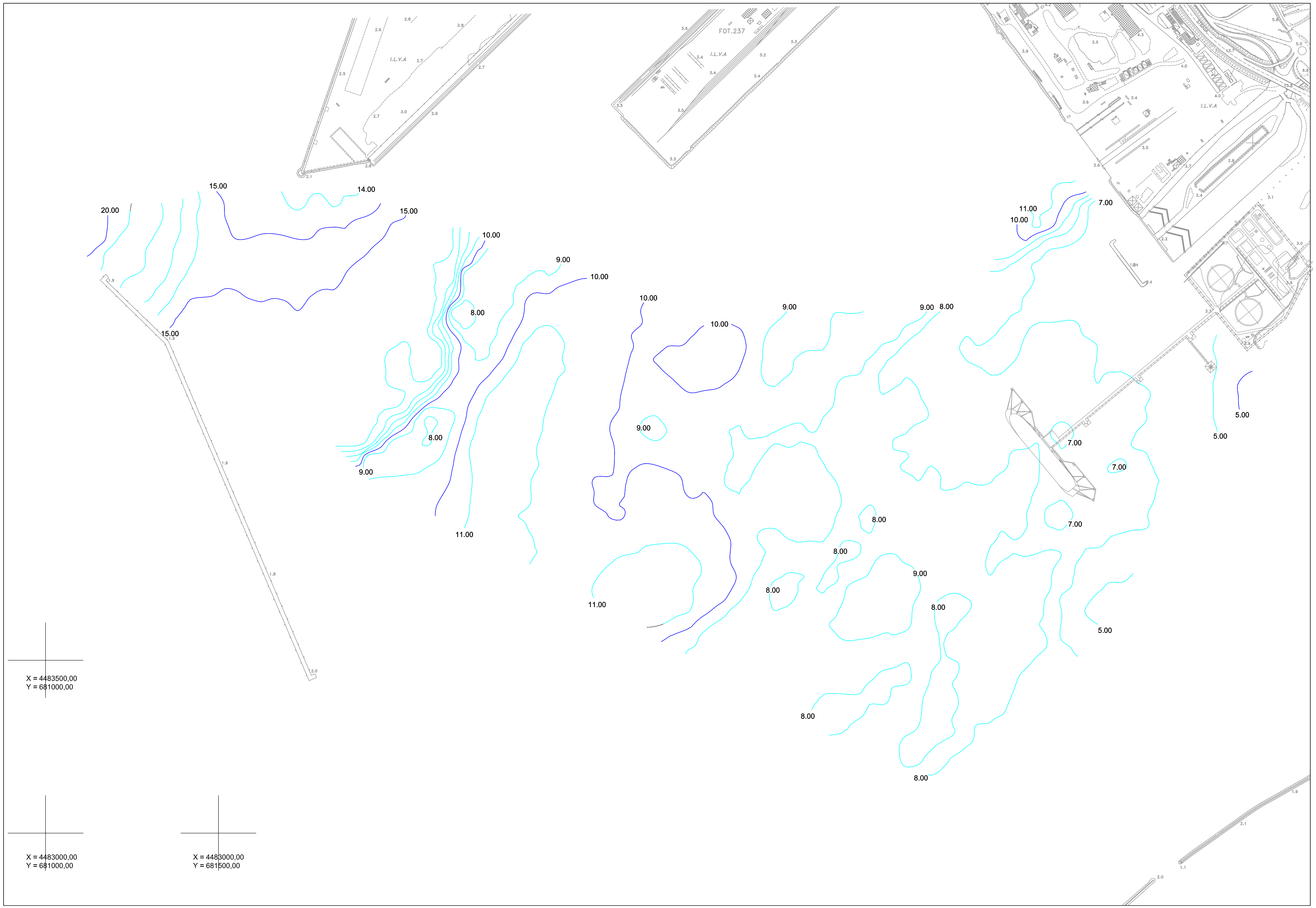
Unit A (from sea-bottom surface to the bottom limit of the superficial unit), formed by mud, clays, fine sands and gravel levels. In this Unit they appear of isolated form outcrops of hardened materials that lean in the inferior subunit.

Unit B drive (from surface of the sea-bottom until the inferior limit of the deeper subunit) formed by fine sands, gravel levels and rest of rock altered (hard clay or marl) in the wall.

Thickness levels have been calculated in accordance with the propagation velocity of the acoustic pulse through the sediment column. In this case, and based on references from previous and similar surveys, a sediment sound propagation velocity of 1750 m/s. has been used. Based on velocity and the double reflection times of acoustic pulse, the equation to calculate the distance of a reflector allows making a very precise conversion of the thickness of non-consolidated sediment, in metres.

Maps show thickness in metres, as well as the curbs connecting places of equal thickness value - known as “Isopaches” - with a1-metre equidistance. The curb with thickness value=0 represents the limit of the sub-bottom with the consolidated material.

DRAWINGS



LEGEND

Master Isobaths (spacing 5 m)

Isobaths (spacing 1 m)

10.00 Sounding in meters

Each sounding is referred to the Mean Sea Level as defined by the Istituto Geografico militare.
Projection UTM 33 Datum WGS84

gasNatural

NUMBER: 1

DATE: December 2004

SCALE: see coordinates

PROJECT:
BASIC PROJECT FOR THE NEW REGASIFICATION TERMINAL FOR LIQUEFIED NATURAL GAS IN THE PORT OF TARANTO, ITALY

MAP:
Bathymetry
Port of Taranto (Taranto, Italy)

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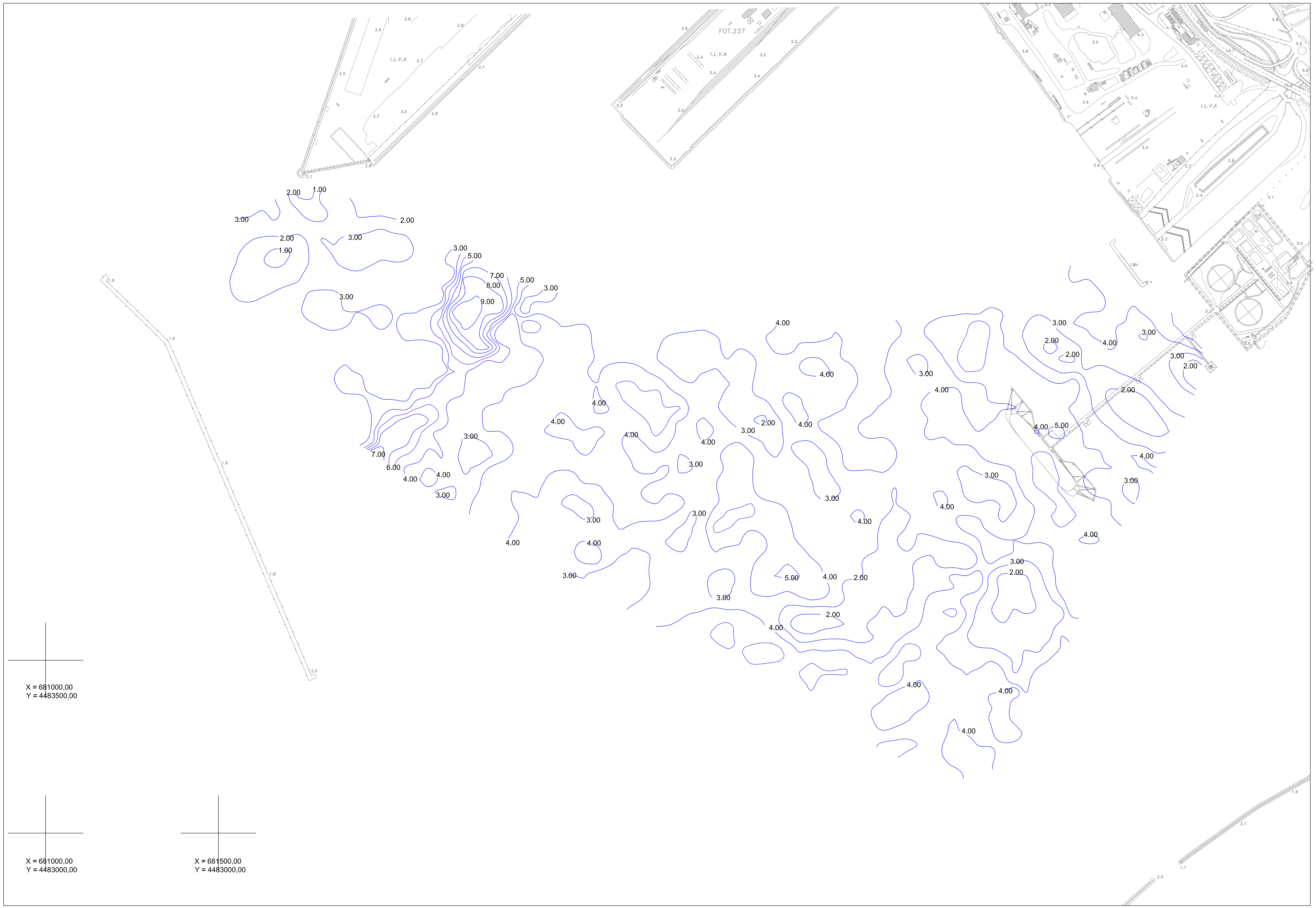

LEGEND

Isopaches (m) of non-consolidated sediment
Unit A

Each value is in meters counted from the sea bottom to the lower limit of Unit A

Projection UTM 33 Datum WGS84

gasNatural

NUMBER: 2	PROJECT: BASIC PROJECT FOR THE NEW REGASIFICATION TERMINAL FOR LIQUEFIED NATURAL GAS IN THE PORT OF TARANTO, ITALY
DATE: December 2004	
SCALE: See coordinates	MAP: Geophysics Port of Taranto: Isopaches of non-consolidated sediment Unit A

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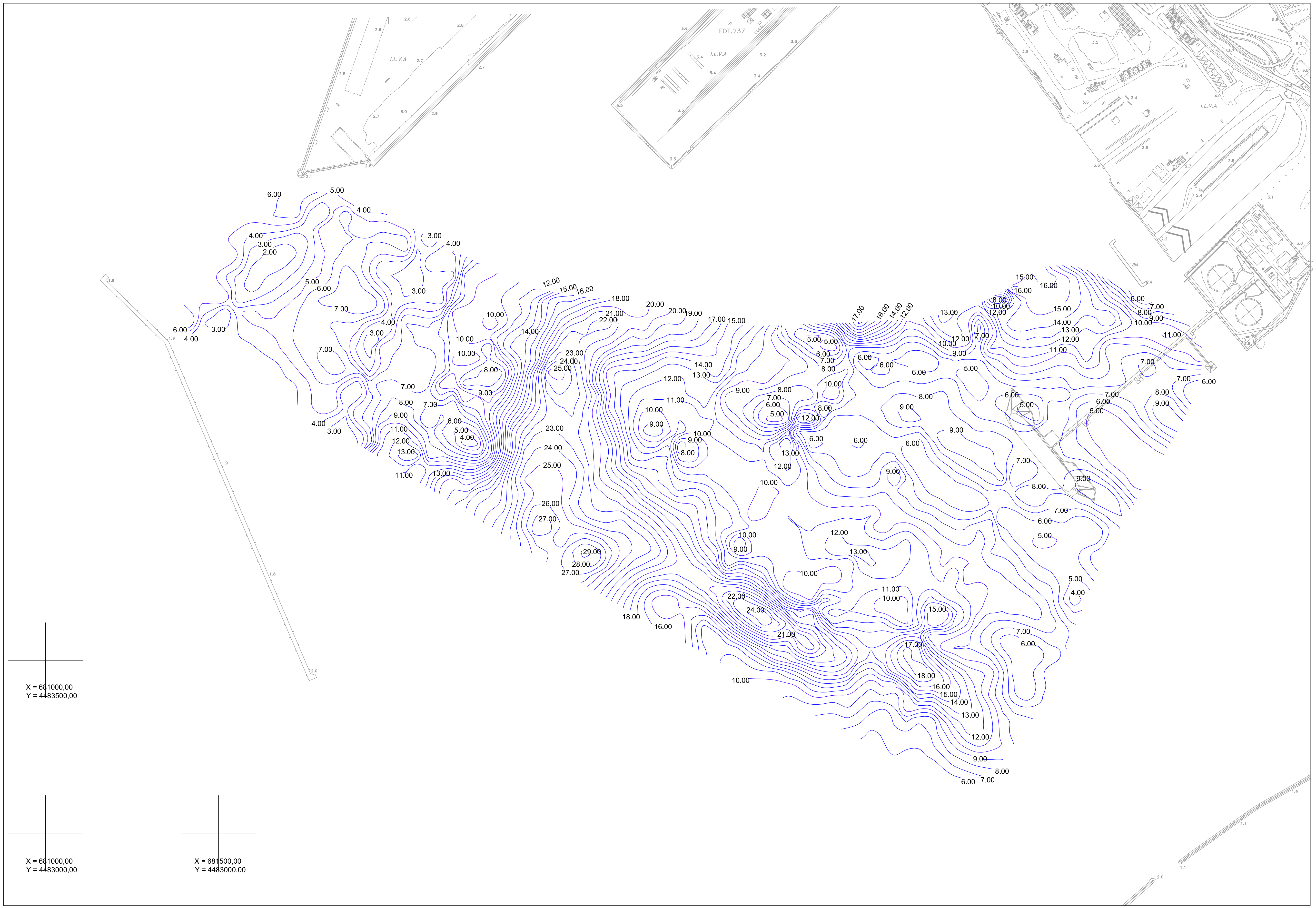

LEGEND

Isopaches (m) of non-consolidated sediment
Unit B

Each value is in meters counted from the sea bottom to the lower limit of Unit B

Projection UTM 33 Datum WGS84

gasNatural

NUMBER: 3 (3 of 3)	PROJECT: **BASIC PROJECT FOR THE NEW REGASIFICATION TERMINAL FOR LIQUEFIED NATURAL GAS IN THE PORT OF TARANTO, ITALY**
DATE: December 2004	
SCALE: See coordinates	MAP: Geophysics Port of Taranto: Isopaches of non-consolidated sediment Unit B

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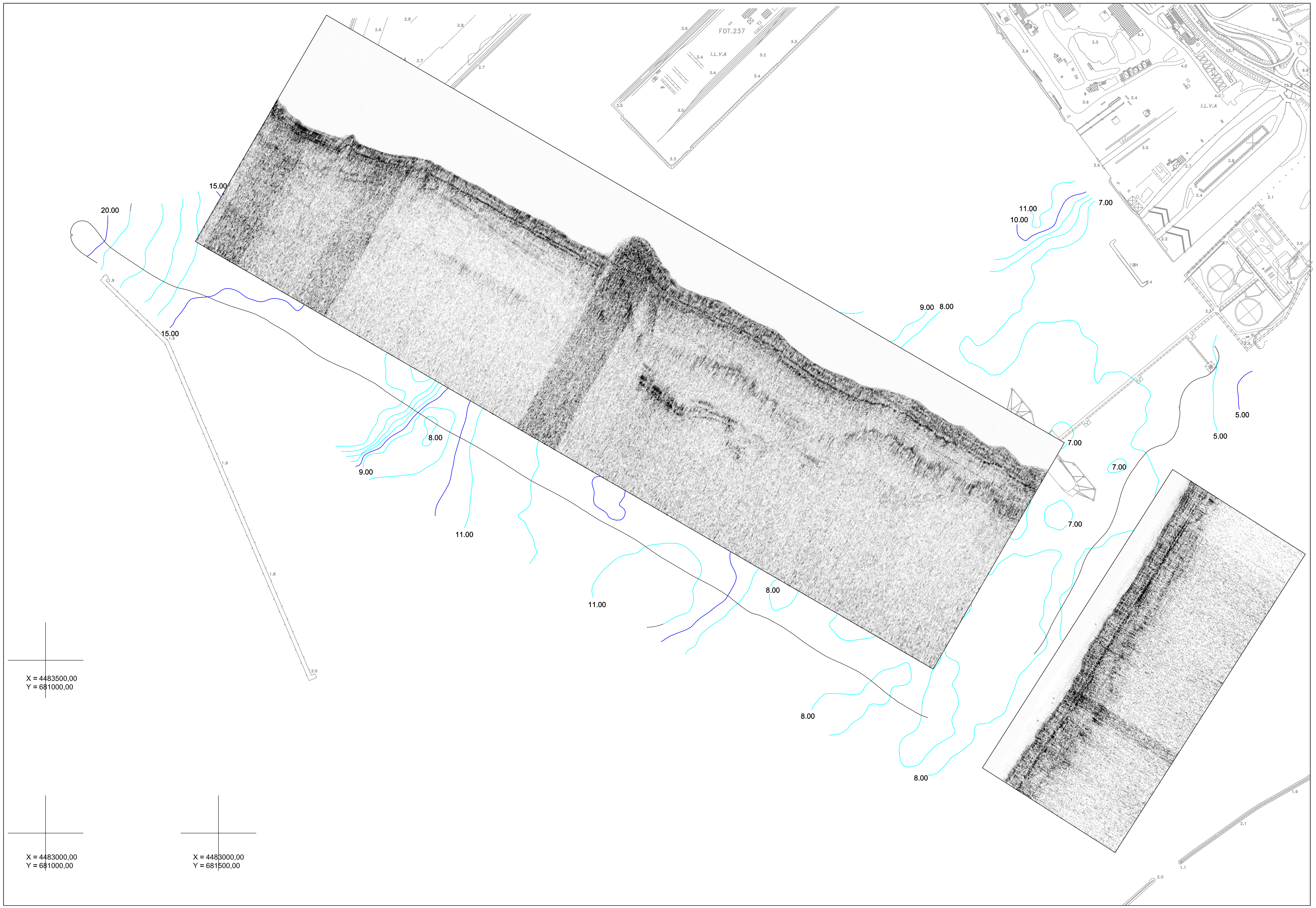

LEGEND

(dark blue line)	Master Isobaths (spacing 5 m)
(cyan line)	Isobaths (spacing 1 m)
(grey line)	geophysical profile
10.00	Sounding in meters

Each sounding is referred to the Mean Sea Level as defined by the Istituto Geografico militare.
Projection UTM 33 Datum WGS84

gasNatural

NUMBER: 4

PROJECT: BASIC PROJECT FOR THE NEW REGASIFICATION TERMINAL FOR LIQUEFIED NATURAL GAS IN THE PORT OF TARANTO, ITALY

DATE: December 2004

SCALE: see coordinates

MAP: Geophysical Profiles
Port of Taranto (Taranto, Italy)

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