Chapter 7: Physical and Geophysical Environment

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7 Physical and Geophysical Environment

7.1 Introduction

This chapter considers the Project's impacts on the physical environment within the Turkish Exclusive Economic Zone (EEZ) of the Black Sea. It identifies physical receptors within the Turkish EEZ (Section 7.2) and provides a description of the baseline conditions (Sections 7.4 and 7.5). Potential impacts on physical receptors associated with the Construction and Pre-Commissioning, Operational and Decommissioning Phases were considered unlikely to be significant and as such have been scoped out of an impact assessment. Information on the rationale for scoping out impacts to physical receptors is given in Section 7.2.

7.2 Scoping

The scope of the physical environment impact assessment for the Project was defined through a process that identified physical receptors and potentially significant impacts related to the Project. Baseline information which informed the scoping process largely drew on information gathered from studies undertaken for the South Stream Offshore Pipeline, including feasibility, engineering and environmental surveys carried out in 2011 to 2012 (Section 7.4). Key steps in the scoping process for the physical environment comprised the following:

- The Project's Front End Engineering and Design (FEED) was reviewed to identify activities with the potential to significantly affect marine physical receptors;
- Physical receptors within the Project Area were identified through a process of secondary data review and surveys undertaken for the Project (Section 7.4) and professional expertise;
- A review of relevant national and international legislative requirements and lender requirements to ensure legislative and policy compliance; and
- An Environmental Issues Identification (ENVIID) was undertaken to assist in the identification of impacts and receptors. During the ENVIID process, each activity was examined to understand how activities were expected to interact with physical receptors, which receptors would be impacted and the nature (positive or negative) of the likely impact. The outcome of the ENVIID was an ENVIID register which identified the various elements of the Project and their interaction or potential impact on sensitive physical receptors.

The following five physical receptors were considered in this chapter:

- Geological processes;
- Hydrodynamic processes;
- Sediment quality;
- Air quality; and
- Water quality.

The Project involves a wide range of activities that could have the potential to impact the physical environment, primarily during the Construction and Pre-commissioning Phase. The relevant activities are summarised in Table 7.1. Decommissioning activities are not known at this time. Good International Industry Practice (GIIP) is usually to leave marine pipelines in situ, which would have impacts indistinguishable from those set out for the Operational Phase. However, for the purposes of this ESIA Report, wholesale pipe removal is also considered, pending a decommissioning assessment to be carried out at a future date.

Table 7.1 Project Activities in the Turkish Marine Environment

Phase	Activity
Construction and Pre-Commissioning	Mobilisation of vessels to and from site and vessel movements within the construction spread (including dynamic positioning).
	Vessel routine operations (including propulsion, cooling water, water maker, bilges and ballast).
	Delivery of pipe and other supplies, as well as crew changes.
	Night time working.
	Laying the pipe on the seabed.
Operation	Physical presence of the Pipeline.
	Pipeline inspection (including ROV surveys etc.) and maintenance that will involve some vessel movements and associated generation of small quantities of wastes associated with routine vessel operations.
Decommissioning (Option 1)	Pipeline cleaning by flushing with water and associated water displacement and disposal.
	Filling pipe with seawater and sealing.
	Vessel operations associated with inspection surveys.
Decommissioning (Option 2)	Lifting of Pipeline from the seabed.
	Seabed intervention, including excavation of buried pipe.
	Associated vessel operations.

The Project has been designed to avoid, minimise or reduce a number of impacts at source through the development of a set of design controls which are set out in Table 7.2. The controls included in Table 7.2 relate to the Construction and Pre-Commissioning, Operational and Decommissioning Phases.

Table 7.2 Design Controls

Design Controls
Water Quality
All vessel discharges and wastes will be compliant with the International Convention for the Prevention of Pollution From Ships (MARPOL) and national regulations, cognisant of the Black Sea's status as an International Maritime Organisation (IMO) special area with respect to garbage and wastes containing hydrocarbons. For information on the regulations governing the discharges of waste and wastewater adopted by the Project refer to **Chapter 12 Waste Management**.
An integrated Waste Management Plan will be drawn up by contractors to ensure wastes are minimised at source, recycled / re-used where possible and otherwise managed responsibly. Adherence to vessel-specific Waste Management Plans which will include provisions for segregating waste on board, having secure areas for storage of hazardous waste and recycling / reuse where practicable.
All bunkering activities will be undertaken in accordance with the Vessels and Marine Transport activity-specific Construction Management Plan (CMP), which will be developed as part of South Stream Transport's Construction Phase Environmental and Social Management Plan (ESMP). The CMP will contain activity-specific requirements, to be met by both South Stream Transport and the appointed contractors (and sub-contractors).
Air Quality
Adherence to national and international legislation regarding fuels.
Systematic monitoring of the condition and the adjustment of the fuel systems of ship equipment.
The main ship engines must be certified in compliance with MARPOL, and priority is given to the equipment which ensures compliance with environmental standards and air protection requirements.
Starting and operating according to manufacturer's recommendations and implanting a schedule of mandatory maintenance to ensure that equipment is functioning properly to minimise emissions.
Maintenance services will monitor the malfunctions of internal combustion engine fuel systems and diagnosing them for the permissible level of harmful substance emissions released into the atmosphere.
As Carbon Dioxide equivalent (CO_2e)* emissions are expected to exceed 25,000 tonnes per year during construction of the South Stream Offshore Pipeline, an inventory of emissions based on actual plant or fuel usage, in order to calculate tonnes emissions per year, will be maintained during construction activities**.

* Equivalent CO2 (CO2e) is the concentration of CO2 that would cause the same level of radiative forcing as a given type and concentration of greenhouse gas.
** International Finance Corporation (IFC) Performance Standard 2012 states that "for projects that are expected to or currently produce more than 25,000 tonnes of CO2-equivalent annually, the client will quantify direct emissions from the facilities owned or controlled within the physical project boundary"

Given the scope of Project Activities (Table 7.1) to be undertaken in the Turkish EEZ, they are unlikely to have any impact on geological and hydrodynamic processes, air and water quality. Therefore an impact assessment, following the methodology given in **Chapter 3 Impact Assessment Methodology**, was not undertaken. As such information on the baseline conditions for these topics has been provided for information only. The rationale for scoping these topics out prior to the impact assessment stage was based on the following:

- Geological processes:
  - There is no scope for Project activities to impact geological processes as there is no seabed intervention. The only activity on the seabed is the placement of pipelines which has no scope to impact geological processes.
- Hydrodynamic processes:
  - The Project activities that could potentially impact hydrodynamic processes (currents, tides, waves) are limited to the physical presence of the pipelines on the seabed. Current speeds at 2,000 metres (m) depth (in which the Project lies) are low (Section 7.5.2.4) and the pipelines will be partially buried as they sink into the soft clayey mud sediments known to occur in the Project Area (Section 7.5.3.5). As such, the potential for Project activities to cause changes in the baseline conditions is limited;
  - The impact would cover a limited area around the pipelines; and
  - In addition, there are no sensitive benthic ecological receptors in the vicinity of the pipelines (**Chapter 8 Biological Environment**) for any changes to hydrodynamic processes to impact.
- Sediment quality:
  - The Project activities that could impact sediment quality include waste / wastewater discharges. All waste discharges from vessels would occur at or near the sea surface (around 2,000 m distance from seabed sediments). Changes in water quality from vessel activities will be localised to the sea surface and around the vessel spread. Any changes are likely to be short-lived as discharges are rapidly diluted and dispersed throughout the water column. As such, there is no potential for Project Activities to cause changes in the baseline conditions of seabed sediment quality;
  - The impact would cover a limited area around the construction vessel for waste discharges and around the pipelines for sediment re-suspension; and
  - There is also potential for re-suspension of sediments from remotely operated vehicle (ROV) use during surveys and the placement of the pipelines on the seabed to impact sediment quality. As the sediments are clayey and will result in limited re-suspension, there are no ecological receptors in the vicinity (**Chapter 8 Biological Environment**), and sediments at that depth are considered unlikely to be contaminated (Section 7.5.3.5), there is no scope for impacts from Project activities on sediment quality.
- Air quality:
  - Construction activities in the Turkish Sector will occur at a distance of at least 110 km from the nearest onshore air quality receptors. The considerable distance from the Project Area to the nearest air quality sensitive receptors (the town of Sinop on the

Turkish mainland) means that pollutants would disperse to the point that the impact on ambient air quality limit values at receptors on land would be **Not Significant** (refer to *impact significance* terminology in **Chapter 3 Impact Assessment Methodology**);

- The area for any modelling assessment of vessel emissions would not include the offshore environment, due to the absence of air quality limit values for assessing impacts upon seawater, marine birds and mammals or other marine biology. A navigation safety exclusion zone of 2 km radius would also be in place centred on the pipe-lay vessel during construction works, which would have the added benefit of avoiding short-term impacts to other marine users from emissions associated with construction vessels;
- The emission source is temporary (approximately 170 days per pipeline). It is also mobile so the impact on a given (stationary) receptor over the course of a year could be considered **Not Significant**;
- Although there is no impact assessment for air quality, a number of design controls measures have been adopted to help minimise any impacts (Table 7.2); and
- The atmospheric emissions have been calculated per pipeline for the Construction Phase of the Project (i.e. the Turkish sector) and are presented in Table 7.3; and

Table 7.3 Atmospheric Emissions from Construction Vessels per Pipeline (tonnes)

Carbon Dioxide (CO_2)	Nitrogen Oxide (NO_X)	Carbon Monoxide (CO)	Particulate Matter (PM)	Sulphur Dioxide (SO_2)	Non-Methane Volatile Organic Compounds (NMVOC)
91,913	2,283	215	44	873	81

- Greenhouse gas (GHG) emissions during the Construction and Pre-Commissioning Phase for the South Stream Offshore Pipeline (Russian, Turkish and Bulgarian sectors) were calculated and are provided in Appendix 7.1 and summarised in **Chapter 5 Project Description** and in Table 7.4. Emissions factors were applied to peak and factored annual fuel consumption to quantify emissions of pollutant averaged out over a year for the long term. CO_2e assumes a greenhouse gas potential of 21 for CH_4, 310 for N_2O and 1 for CO_2. For more information on the methodology used to calculate the GHG, refer to Appendix 7.1: Atmospheric Emissions from the South Stream Offshore Pipeline – Turkish Sector; Construction and Pre-Commissioning Phase.

Table 7.4 Total Greenhouse Gas Emissions during Construction and Pre-Commissioning Phase for all 4 pipelines (tonnes CO_2e)

Russian Sector	Turkish Sector	Bulgarian Sector	Total South Stream Offshore Pipeline System
674,853	94,061	1,003,787	1,772,701

- Water quality:
  - Changes in sediment quality or disturbance of sediments can impact water quality. As stated above, there is no scope for impacts from Project Activities on sediment quality. The Project Activities that could potentially cause disturbance of seabed sediments are ROV use during surveys and the physical presence of pipelines on the seabed. The re-suspension of sediments from these activities could cause changes in deep sea water quality. However, as stated in Section 7.5.3.5, the seabed sediments within the Survey Area at these depths are not considered contaminated;
  - Changes in water quality from vessel activities such as from waste or wastewater discharges will be localised to the sea surface and around the vessel spread. Any changes are likely to be short-lived as discharges are rapidly diluted and dispersed throughout the water column;
  - Changes in water quality have more relevance for indirect impacts on ecological receptors. The indirect impacts of water quality on marine ecology are discussed in **Chapter 8 Biological Environment**;
  - The impact area would cover a limited area around the construction vessel for waste discharges and around the pipelines for sediment re-suspension;
  - Given the above, it could therefore be assumed that the impact area from water quality impacts is localised and Project activities are likely to be **Not Significant** (refer to *impact significance* terminology in **Chapter 3 Impact Assessment Methodology**); and
  - Although there is no impact assessment for water quality, a number of design controls have been adopted to help minimise any impacts (Table 7.2).

As such, no impact assessment was carried out for the physical environment.

7.3 Spatial and Temporal Boundaries

The Project Area is some 470 km in length and 2 km in width, extending along an east west orientation across the north of the Turkish EEZ. Information on Project Area is given in **Chapter 1 Introduction**.

The Study Area for this chapter is defined as the entire abyssal plain of the Black Sea encompassing the Turkish EEZ as physical features of the Black Sea are wide reaching and linked with the features of the entire abyssal plain Black Sea environment.

The Survey Area(s) refers to the area(s) in which surveys were undertaken for the Project during the feasibility and development stages in 2011 and 2012 (Section 7.4). The extents of the Survey Area(s) vary for some receptors and are shown in 7.4.1 to 7.4.4.

7.4 Baseline Data

Secondary data (i.e. data from third parties not specifically acquired for the Project, including literature reviews etc.) and existing primary data (i.e. data acquired specifically for this Project through dedicated surveys) were reviewed prior to scoping. Following this, a data gap analysis was conducted and surveys to collect additional primary data were specified.

The majority of the baseline information used to support this chapter comes from primary data such as the results of marine surveys specifically conducted for the Project in 2011 (Ref. 7.1), and in 2012 (Ref. 7.2). Details of the survey scopes are given in Section 7.4.1 to Section 7.4.4.

7.4.1 Methodology and Data

In order to provide context for the assessment of environmental impacts (discussed in subsequent chapters), baseline information on the physical environment of the region has been collected.

Secondary (i.e. existing data based on desk-based research) and primary data regarding the relevant baseline characteristics have been identified and assessed. Primary data was collected during field surveys. Data on the surveys and methodologies for data collection is given in Section 7.4.4. Information on secondary data used is given in Section 7.4.2.

7.4.2 Secondary Data

Where possible, this assessment is based on primary data. Secondary data were also consulted to inform the baseline of this chapter, as described below:

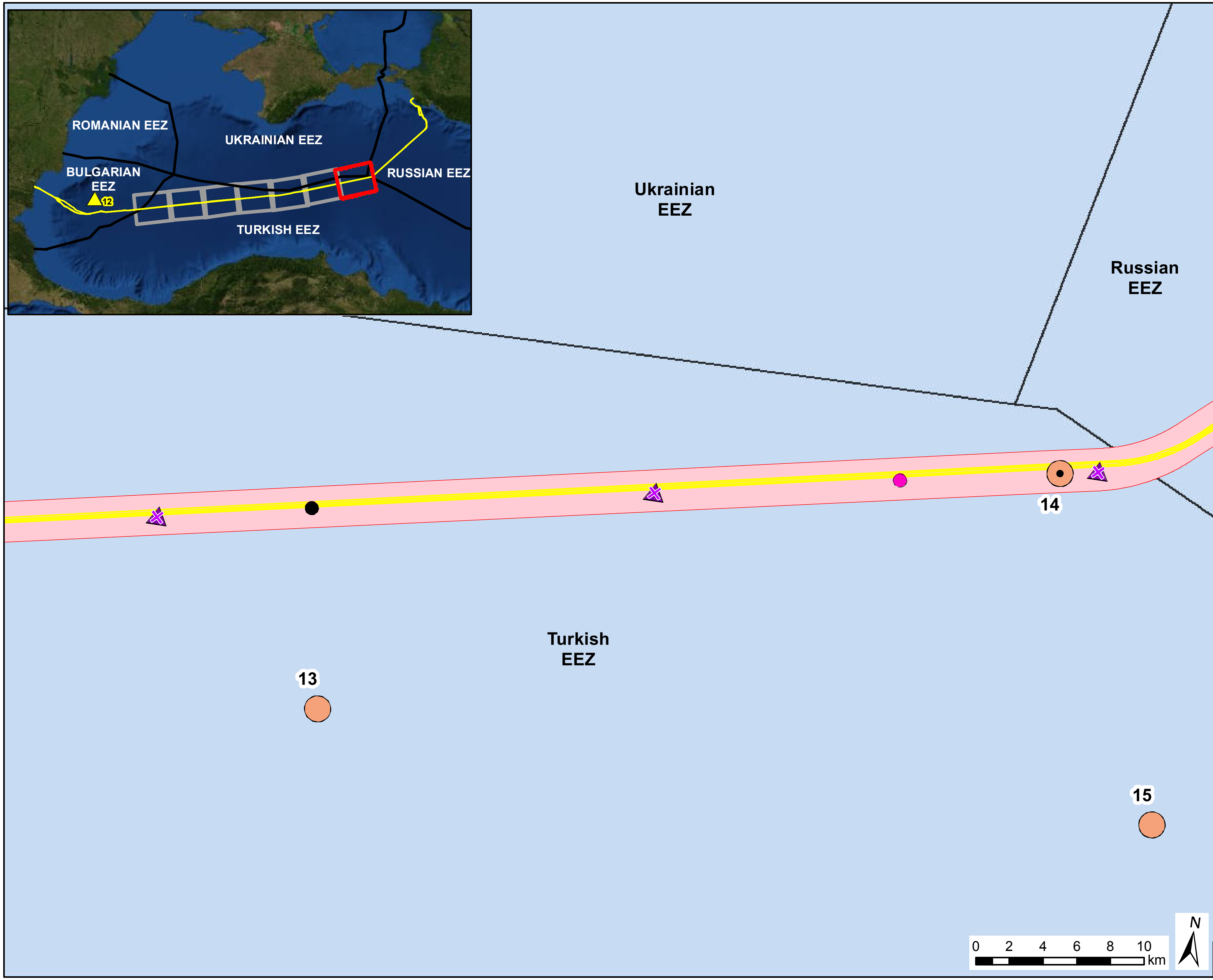
- The 2011 survey reports (Ref. 7.1) included a thorough review of published scientific literature that has been incorporated into this baseline as appropriate;
- Other recent published scientific literature was identified through a British Library data search;
- The Black Sea Meteorological Atlas, prepared by the Turkish Naval Force in 1991 which includes the meteorological conditions of the Black Sea (Ref. 7.3); and
- Meteorological modelling was one of the tools used to identify the meteorological features of the Project Area. The second version of the Climate Forecast System (CFS), i.e. software developed by National Climatic Data Centre (NCDC), was used to generate high resolution historical data in the Project Area (Ref. 7.4).

7.4.3 Data Gaps

As part of the data collection exercise, a gap analysis was conducted to identify any areas where existing baseline data were insufficiently detailed to allow for a robust assessment. However, the data collected from the primary survey data and secondary sources was considered sufficient for the identification of a robust baseline.

7.4.4 Primary Data / Baseline Surveys

A summary of all survey data collected for the Project is given in Table 7.5 and shown in Figure 7.1 to Figure 7.7.



LEGEND

- Marine geophysical / geotechnical Survey & Analysis of geological anomalies
- Metocean Surveys

Marine Sediment Surveys

- Chemical Sampling Locations
- CPT Sampling Locations
- Gravity Core Sampling Locations
- Box Core Sampling Locations
- Piston Core Sampling Locations

Marine Oceanography / Hydrochemistry Surveys

- 1 Water quality sampling locations
- 1 Sediment sampling locations
- 1 Oceanography/ hydrochemistry surveys

Turkish Sector of South Stream Offshore Pipeline

- Proposed offshore pipelines
- Exclusive Economic Zones
- Isobaths

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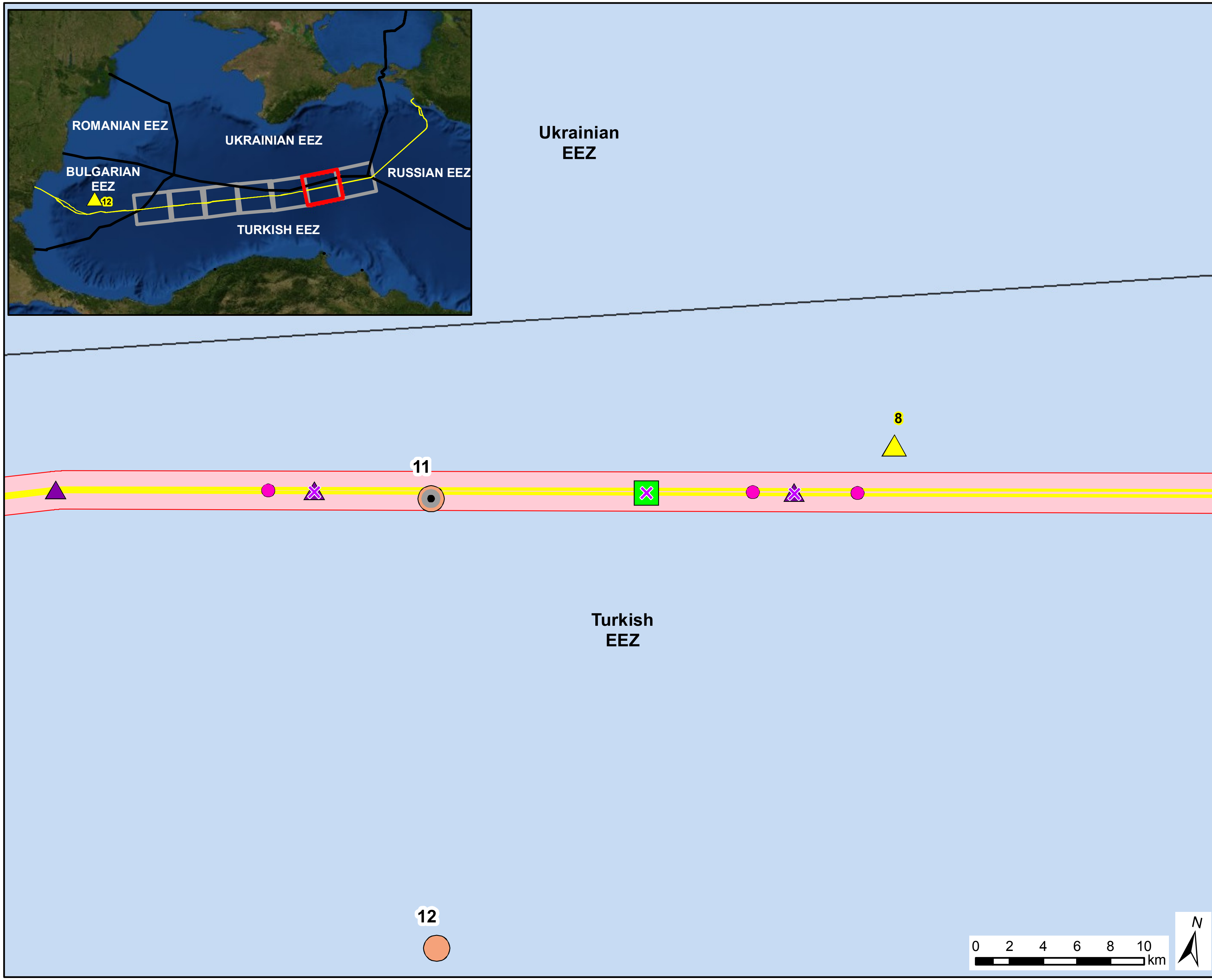

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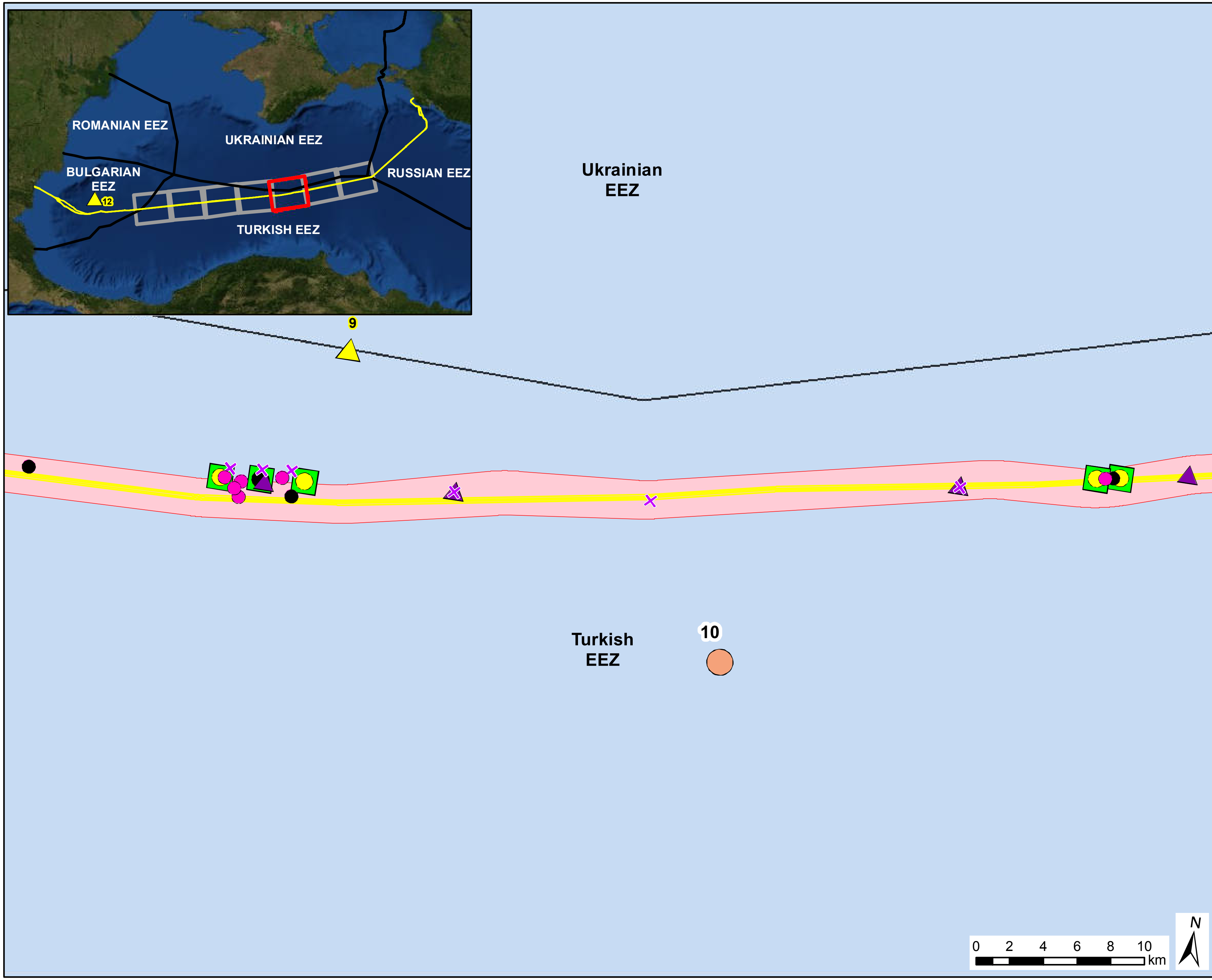

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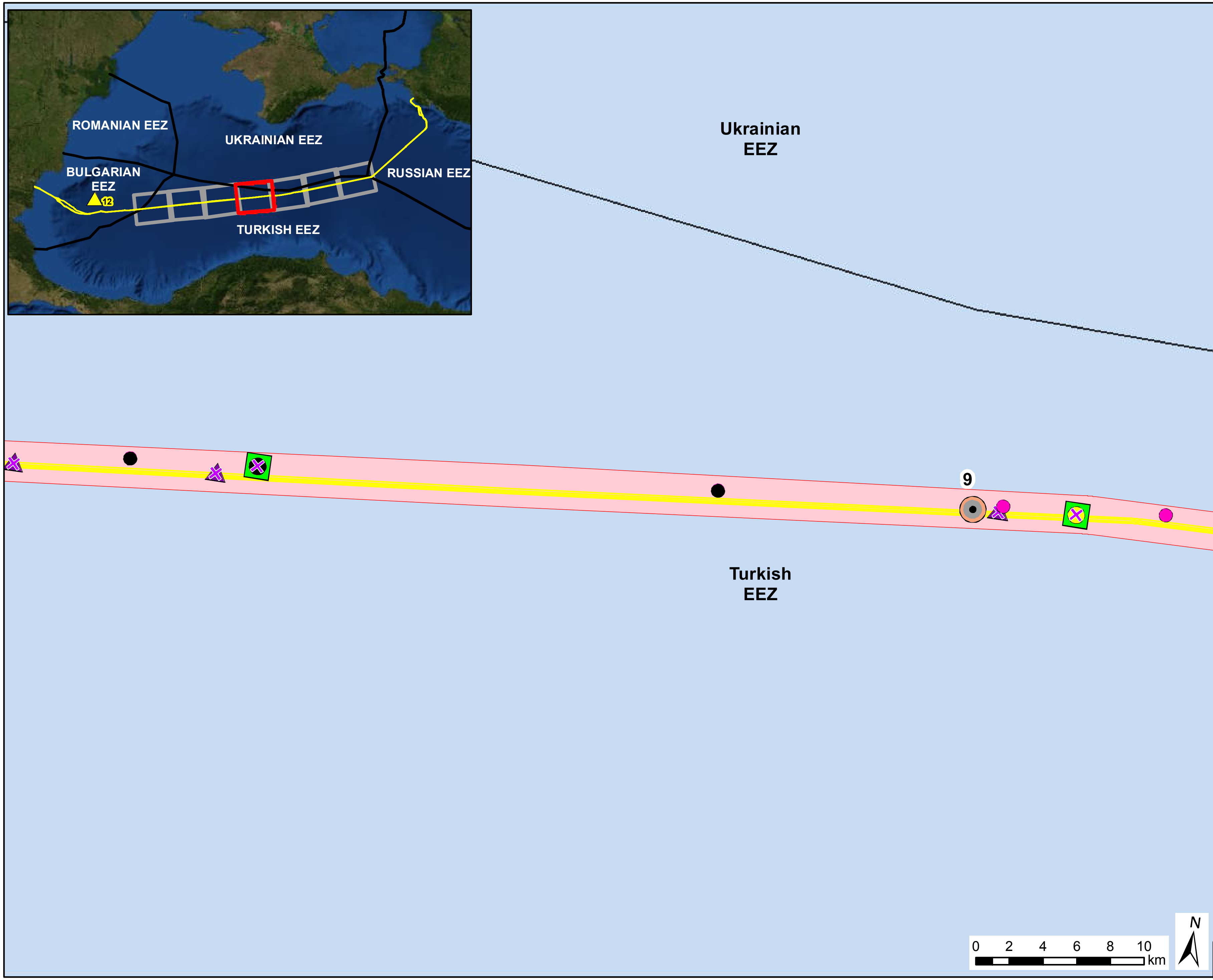

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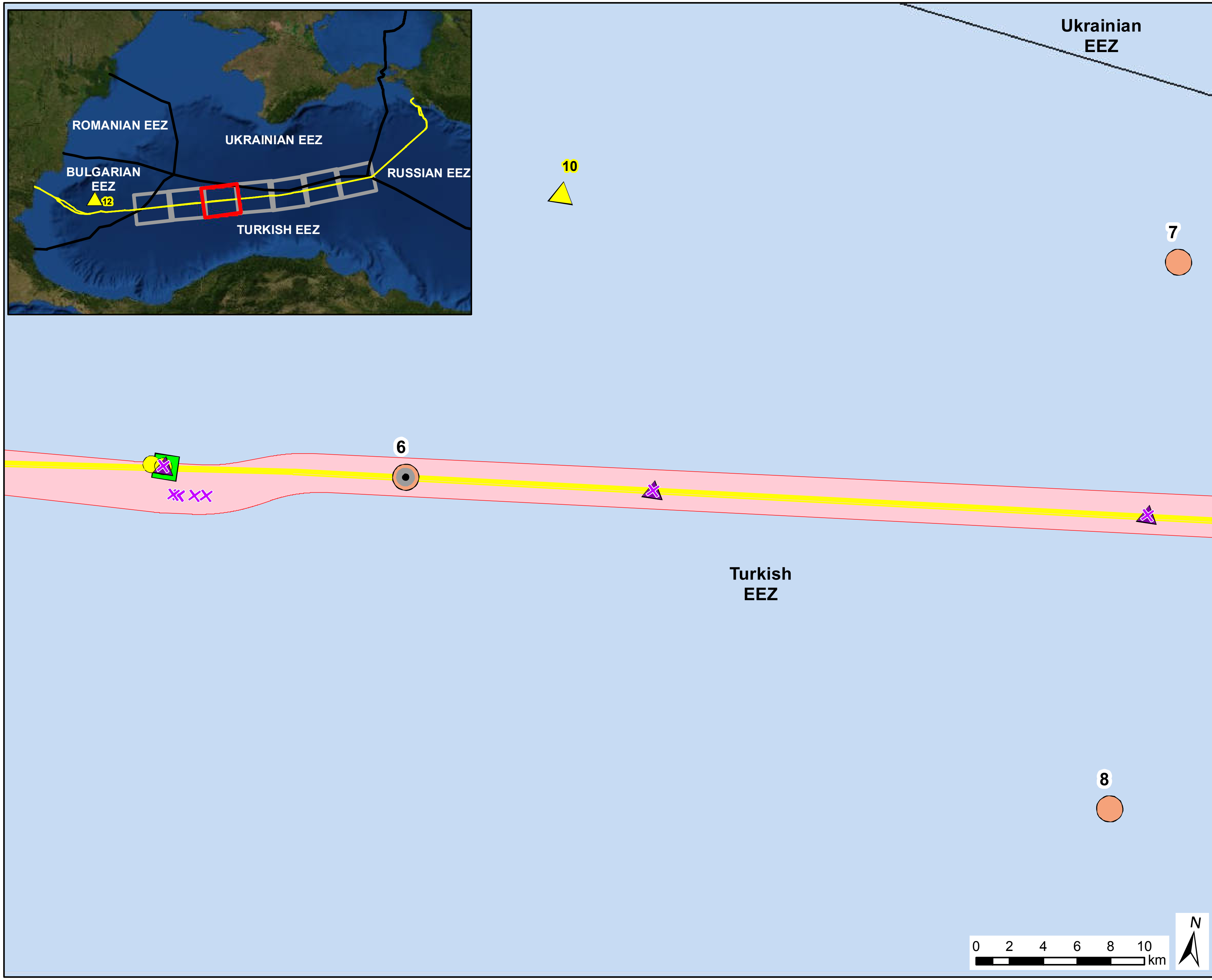

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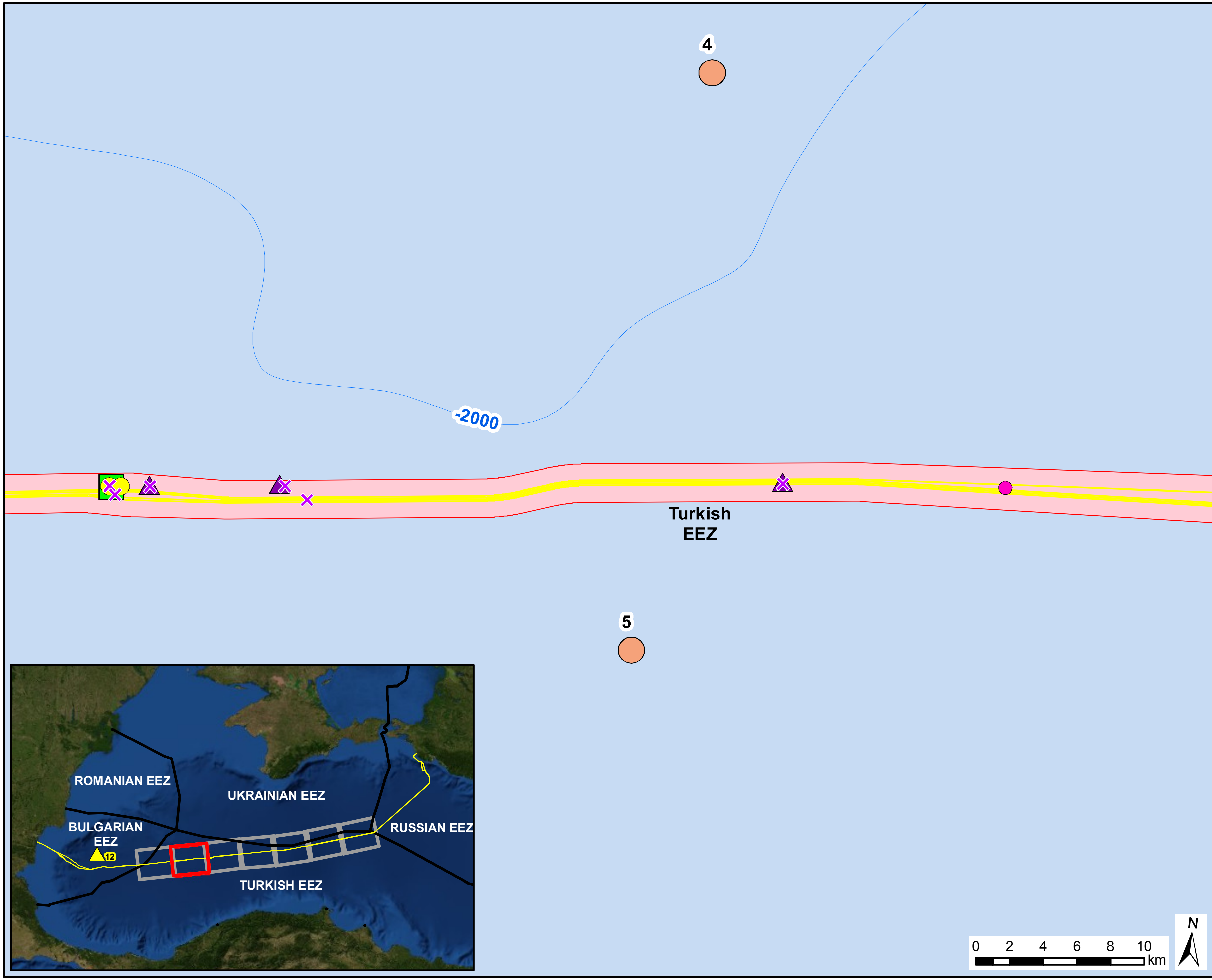

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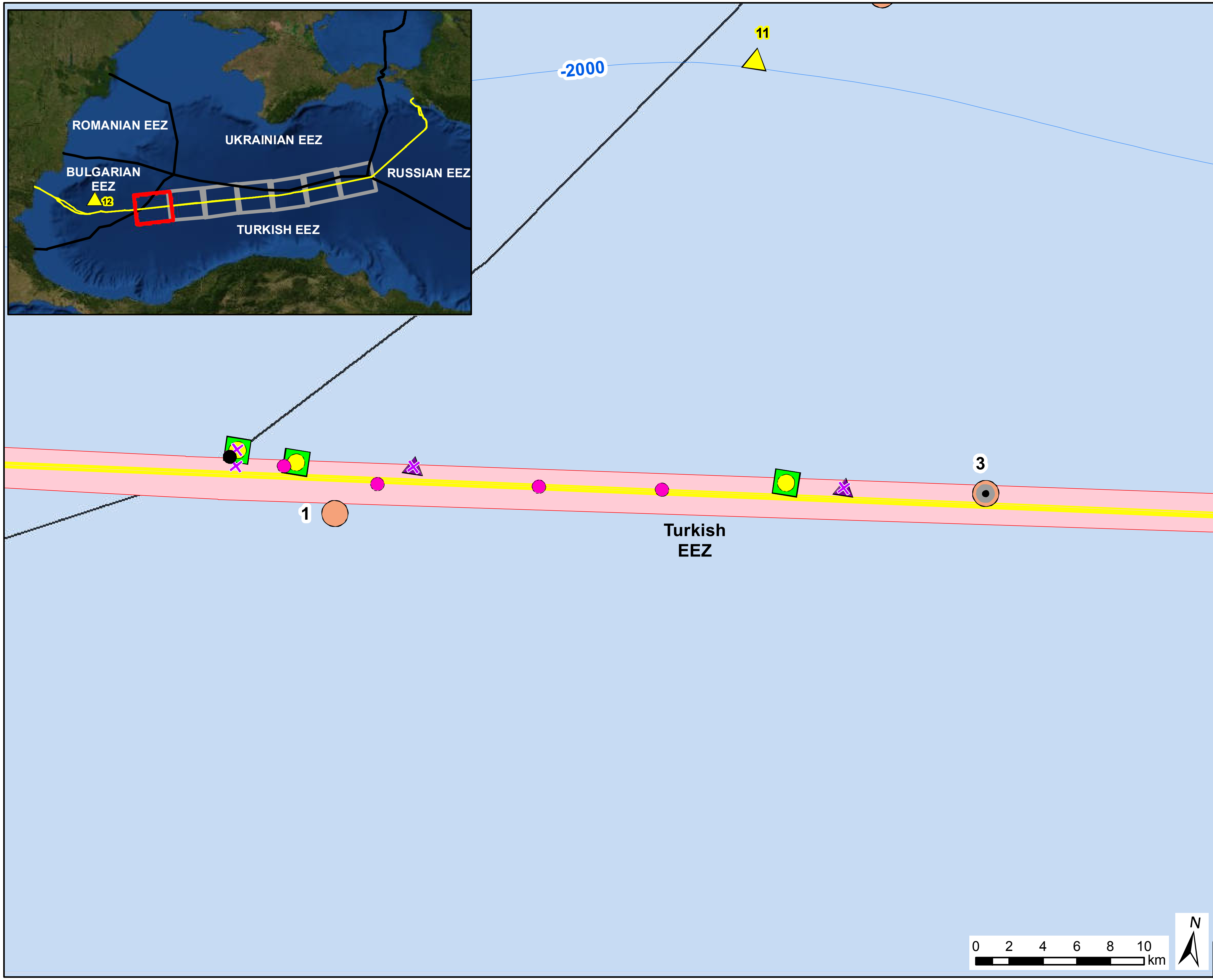

LEGEND

Marine geophysical / geotechnical Survey & Analysis of geological anomalies

Metocean Surveys

Marine Sediment Surveys

Chemical Sampling Locations

CPT Sampling Locations

Gravity Core Sampling Locations

Box Core Sampling Locations

Piston Core Sampling Locations

Marine Oceanography / Hydrochemistry Surveys

1 Water quality sampling locations

1 Sediment sampling locations

1 Oceanography/ hydrochemistry surveys

Turkish Sector of South Stream Offshore Pipeline

Proposed offshore pipelines

Exclusive Economic Zones

Isobaths

Projection: Lambert Conformal Conic

Revision Details	By / Check	Check Date	Suffix

Purpose of Issue

For Information

Client

South Stream Offshore Pipeline ENERGISING EUROPE

Project Title

SOUTH STREAM OFFSHORE PIPELINE

Drawing Title

SURVEY AREA FOR PHYSICAL ENVIRONMENT

Drawn	Checked	Approved	Date
JM	CP	MW	10/09/2013

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Drawing Number	Rev
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Table 7.5 Summary of all Physical Surveys

Survey	Month, Year	Type of Survey
Metocean Surveys	May to Dec 2011	Oceanography (wave height, temperature, salinity, sea levels).
Marine Oceanography / Hydrochemistry Surveys	Sep to Oct 2011	Hydrochemistry, water and sediment quality.
Marine Geophysical / Geotechnical Survey	Sep to Oct 2011	Multi beam echo sounder, side scan sonar and sub bottom profiler.
Marine Sediment Surveys	Sep to Oct 2011	Sediment characteristics.
Analysis of Geological Anomalies	Sep 2012	Investigating unknown sonar contacts and/or geological anomalies.

7.4.4.1 Metocean Surveys

Five Autonomous Buoy Stations (ABS) were placed to collect Metocean data within the Survey Area (ABS 8 to 12). The Metocean data collection program, over the period from May 2011 to December 2011, is summarised in Table 7.6. Data for the Survey Area was collected using Recording Current Meter 9 Light Weight (RCM 9 LW), Recording Current Meter 9 Intermediate Water (RCM 9 IW), Recording Current Meter Seaguard (RCM Seaguard) with current, temperature and salinity sensors (Ref. 7.1).

Measurement and sampling were conducted using conductivity-temperature-depth (CTD)-complex "Sea-Bird" ("SBE 911 plus"), equipped with sensors for temperature, electro-conductivity and pressure, with the rosette "SBE 32 carousel" (12 5-litre bathometers) (Ref. 7.1). The temperature and salinity data obtained were processed using software from the manufacturer of the probe. Analysis of samples was either conducted onboard or forwarded to accredited laboratories.

Table 7.6 Metocean Data Collection

ABS	Location (WGS-84) Depth, m	Start of Observations	Service at the 3rd Stage	Quantity of days	Volume of Data Collected	Observed Parameters
8	43°17.22′ N 35°12.12′ E 2,150 m	23 May 2011	30 Nov 2011	191	100%	Current velocity and direction, sea level, water temperature and salinity

Continued…

ABS	Location (WGS-84) Depth, m	Start of Observations	Service at the 3rd Stage	Quantity of days	Volume of Data Collected	Observed Parameters
9	43°08.80′ N 33°57.60′ E 2,175 m				0%*	
10	43°06.36′ N 32°26.82′ E 2,055 m	19 May 2011	1 Dec 2011	196	100%	Current velocity and direction, sea level, water temperature and salinity
11	43°02.86′ N 30°54.93′ E 2,025 m	19 May 2011	2 Nov 2011	197	100%	Current velocity and direction, sea level, water temperature and salinity
12	42°58.26′ N 29°24.83′ E 1,968 m	20 May 2011	2 Dec 2011	195	100%	Current velocity and direction, sea level, water temperature and salinity

* ABS – 9 was lost and therefore no data could be collected.

Complete.

7.4.4.2 Marine Oceanography / Hydrochemistry Surveys

The oceanographic / hydrochemistry survey was conducted in September to October 2011, to assess hydro-chemical and water contamination. Water samples were collected at 15 locations in the Survey Area in 2011 (Figure 7.1). The studies included collection and analysis of 51 samples collected at:

- Twelve stations (No 1, 2, 4 to 8, 10 to 13 and 15) along the surface (0 m), pycnocline (approximately 150 m depth) and hydrogen sulphide boundary layer (approximately 200 m depth); and
- Three stations (No 3, 9 and 14) along the surface (0 m), pycnocline layer (approximately 150 m), hydrogen sulphide boundary layer (approximately 200 m depth), at a depth of 1,000 m and the seabed (approximately 2,000 m depth).

The hydro-chemical testing included Dissolved Oxygen, Ammonium Nitrogen ($N\text{-}NH_4$), pH, Biochemical Oxygen Demand (BOD5), Phosphate ($PO_4\text{-}P$), Total and Organic Phosphorus, Nitrite ($N\text{-}NO_2$), Nitrate ($N\text{-}NO_3$), Total and Organic Nitrogen, Silicate (Si), Hydrogen Sulphide (H_2S) and Alkalinity. Testing was undertaken at:

- Two stations (No 6 and 11) along the surface (0 m), pycnocline (approximately 150 m depth) and hydrogen sulphide layer (approximately 200 m depth); and

- Three stations (No 3, 9 and 14) along the surface (0 m), pycnocline layer (approximately 150 m), hydrogen sulphide boundary layer (approximately 200 m depth), depth of 1,000 m and the seabed (approximately 2,000 m depth).

The list of tested components included: petroleum hydrocarbons, AS (anionic surfactants), organochlorine pesticides, phenols, suspended substances, manganese, arsenic, iron, mercury, nickel, lead, cadmium, zinc, chromium, copper, selenium and molybdenum. Analysis of samples was conducted at accredited laboratories.

7.4.4.3 Marine Geophysical / Geotechnical Survey

Engineering surveys were conducted during the Development Phase of the Project. The survey conducted in autumn 2011 in the Survey Area (Figure 7.1 to Figure 7.7) aimed to identify bottom topography features; evaluate the seabed morphology and subsurface geology and detect potential hazard objects and bottom topography features.

The measuring and sampling instruments included:

- Sound Velocity Profiler (SVP);
- Multi-Beam Echo Sounder (MBES);
- Single-Beam Echo Sounder (SBES);
- Sub-bottom Profiling (SBP);
- High-Frequency Sub-bottom Profiling (HF SBP);
- Low-Frequency Sub-bottom Profiling (LF SBP);
- Side-Scan Sonar (SSS);
- Autonomic underwater vehicle (AUV) and remotely operated vehicles (ROV); and
- Cone Penetration Test (CPT), piston and grab samplers.

7.4.4.4 Marine Sediment Surveys

Sediments were collected in 2011 from four stations (3, 6, 9 and 11) and tested for grain size, organic content and pH. Sediments were also collected using corers which were tested for anionic surfactants (AS), manganese, arsenic, iron, mercury, nickel, lead, cadmium, zinc, chromium, copper, selenium and molybdenum, petroleum hydrocarbons and phenol concentrations at all stations. Two hundred and forty six (246) sediment samples taken from sediment depths of between 0 to 7 m were tested for the above parameters.

7.4.4.5 Analysis of Geophysical Anomalies

In 2012, sonar anomalies identified within the 2 km wide Project Area underwent further investigation using ROV as part of a geotechnical survey of the Survey Area. Anomalies identified from analysis of SSS data were targeted by ROVs for subsequent visual investigation.

7.4.5 Data Assumptions and Limitations

In order to carry out this assessment, certain assumptions have been made regarding the input data, and it is acknowledged that some of the data used in this ESIA Report have attendant limitations:

- The assessment is based on FEED and a project description that continues to be refined. Nonetheless, the key design parameters are understood and the ESIA Report is based on these, with additional mitigations specified as appropriate; and
- Environmental standards may evolve during the lifetime of the Project. It is not possible to predict such changes but reference to Good International Industry Practice (GIIP) minimises the effect of this uncertainty.

7.5 Baseline Characteristics

7.5.1 Meteorological Conditions

The climate of the Black Sea is generally characterised as being continental with some pronounced seasonal temperature variations. In winter, the Black Sea is under the influence of both low pressure weather systems moving from Europe with winds from the west and high pressure weather systems with winds from the northeast from Siberia. In summer, the region is under the influence of high pressure weather systems from North Africa, as well as low pressure systems travelling from Europe (Ref. 7.1).

The average January air temperature over the central portion of the Black Sea is around 8°C decreasing towards the north, east and west, whilst average air temperatures in July reach around 24°C. Temperatures at the far north and south extremities of the Black Sea can vary significantly from those experienced at the centre (Ref. 7.1).

The wind regime is cyclic, with light breezes from May to September being replaced in winter by cold north easterly winds that often reach gale force. The predominant direction of the spring and summer winds is from the west and south-west as well as from the south. Of note is that the greatest number of days with strong winds in summer reaches only three to five. In autumn and winter the winds predominately blow from the northern, north-eastern and eastern areas. The maximum speed of up to 40 metres per second (m/s), with the largest number of days of strong winds (October to March), equal to 12 to 15 (Ref. 7.1).

The Project runs through the Turkish EEZ without the use of any onshore facilities in Turkey. There are no records that have been collected by the Turkish State Meteorological Service along the Project Area. Meteorological models and literature surveys were used to identify the meteorological characteristics.

Meteorological modelling using the second version of the Climate Forecast System (CFS) was used to generate high resolution historical data in the Project Area (Ref 7.4). Three locations along the route were simulated for this ESIA Report. The locations were chosen as the endpoints (borders of the EEZ) and the midpoint. The point coordinates are in Table 7.7.

Table 7.7 Coordinates of the Points where Meteorological Data were Simulated

Point No	Location	Coordinates
1	Eastern Endpoint (Russian EEZ Border)	30°35'57.6"E, 42°49'16.9"N
2	Midpoint	36°16'23.8"E, 43°24'0.6"N
3	Western Endpoint (Bulgarian EEZ Border)	33°24'0.20"E, 43° 9'25.44"N

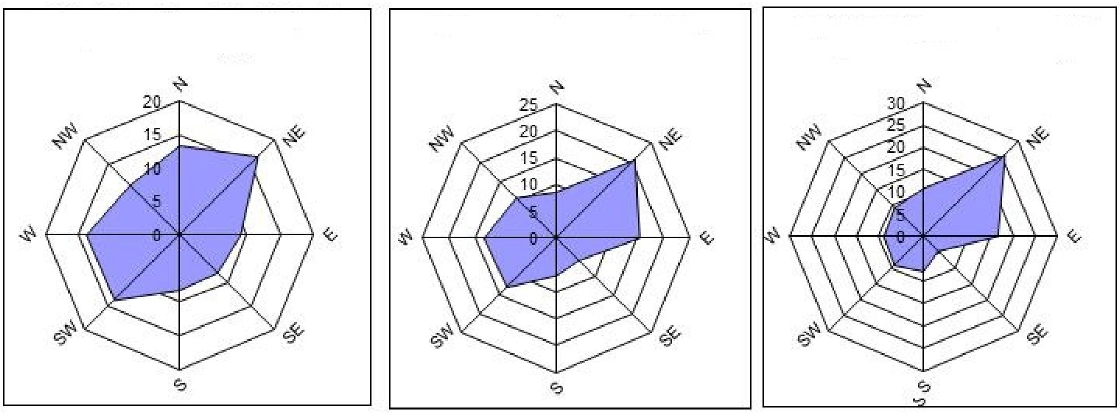
The modelling results predict the annual average atmospheric pressure along the Project Area to be 1,017.41 hPa, 1,017.58 hPa, and 1,017.25 hPa at the Eastern, Mid and Western points, respectively (Ref. 7.4). The annual average temperature from the modelling (Ref. 7.4) was calculated to be 15.61 ^{o}C, 15.47 ^{o}C and 15.65 ^{o}C at the Eastern, Mid and Western points, respectively. The average temperature values along the Project Area are given in Table 7.8.

Table 7.8 Average Temperature Values along the Project Area

Region	Jan.	Feb.	Mar	April	May	June	July	Aug	Sep.	Oct.	Nov.	Dec.	Annual
East	6.1	6.4	8.3	13.1	17.5	21.0	24.7	24.2	21.6	17.7	13.0	13.8	15.61
Mid	5.5	6.7	8.7	13.2	17.4	20.3	25.1	24.2	21.0	17.6	12.7	13.3	15.47
West	5.7	6.1	9.0	13.5	17.4	20.7	24.7	25.0	21.4	18.1	12.9	13.3	15.65

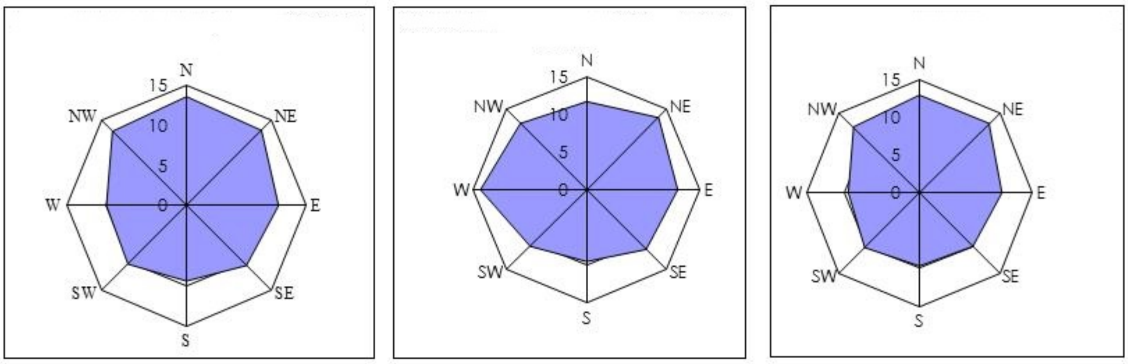
Long-term wind frequency data information was obtained from the Black Sea Meteorological Atlas prepared by Turkish Naval Force (Ref. 7.3). Wind blowing frequencies in all directions on the Eastern, Mid and Western Points of the Project Area are given in Figure 7.8.

Figure 7.8 Diagram of Long-Term Wind Blowing Directional Frequencies for East, Mid and West Regions (%)



The average long-term wind speed values in all directions according to the Black Sea Meteorological Atlas (Ref. 7.3) are shown in Figure 7.9.

Figure 7.9 Diagram of Long Term Average Wind Speeds for all Wind Directions East, Mid and West Regions



7.5.2 Oceanography

7.5.2.1 Bathymetry

The Black Sea is a semi-enclosed sea connected to the shallow (10 to 20 m deep) Sea of Azov through the Kerch Straits and to the Mediterranean Sea through the Bosporus Strait, the Marmara Sea and the Dardanelles Strait.

Black Sea bathymetry is characterised by a relatively narrow coastal shelf running along the perimeter of a very deep and relatively flat interior basin. The northwest area is the only area with a coastal shelf of any significant extent. Here the sedimentary discharge plains of the Danube, Dnieper, Dniester, and Yuzhny (South) Bug Rivers extend a considerable distance offshore (Ref. 7.5).

Water depth within the Project Area varies from 2,025 to 2,199 m. The eastern part of the Survey Area is the deepest and is essentially flat. The western part has more irregular bathymetry, resulting from a complex series of channel levee systems that cross this area. This forms an elevated ridge that rises about 50 m above the main abyssal plain and represents the distal part of the Danube Fan.

The overall bathymetry in the Black Sea can be seen in Figure 7.10. An exaggerated bathymetric profile of the Survey Area is given in Figure 7.11.

Figure 7.10 Bathymetry of the Black Sea

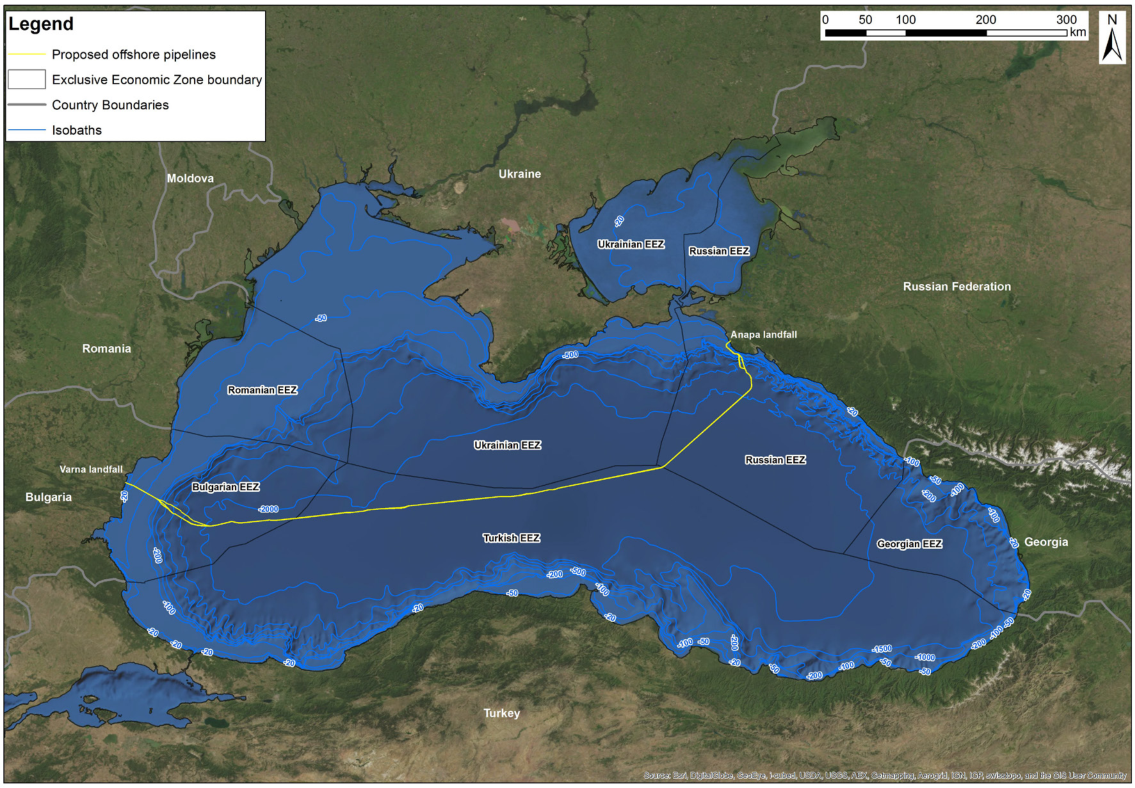
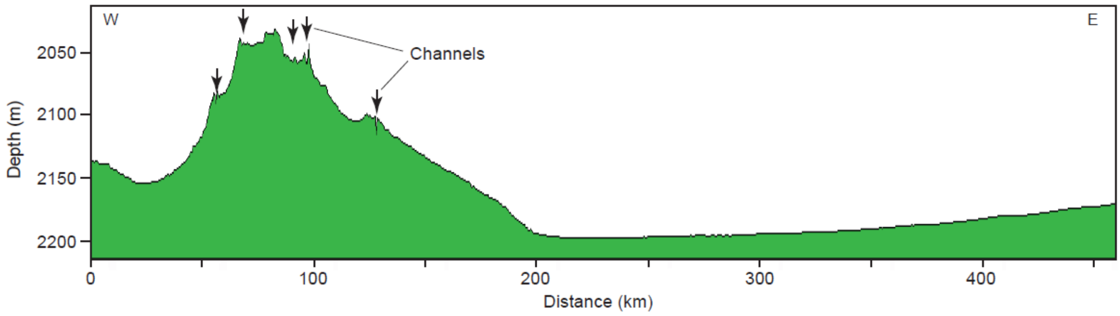


Figure 7.11 Highly Exaggerated Bathymetric Profile along the Project Area



Source: Ref. 7.1

7.5.2.2 Sea Level Variation

The Black Sea is practically non-tidal with a maximum range of no more than 10 centimetres (cm). Short-term sea level variations are associated with varying meteorological conditions and can result in localised sea level surges of up to 20 cm.

Much more significant sea level variations have, however, occurred in pre-historic times, associated with the tectonic events that led to the opening of the Bosphorus Strait. It is now believed that up to 5,000 to 6,000 B.C the Black Sea was a fresh water lake with a surface elevation approximately 30 m below the current levels. Flooding may have occurred as a sudden event associated with large scale seismic activity in the Bosphorus area or gradually, as a result of oscillations in the elevation of the Bosphorus that may have started as early as 30,000 years ago (Ref. 7.1).

Changes in water levels in the Black Sea are thus primarily caused by one or more of the following factors:

- Inter-annual fluctuations in the sea level;
- Seasonal fluctuation as a result of seasonal atmospheric dynamics (e.g. temperature, wind, rainfall and storms);
- River flows;
- Spatial changes in the atmospheric pressure; and
- Natural temporal and spatial variability in dynamics of the water column.

Metocean data collected along the Survey Area in 2011 (Ref. 7.1) is summarised in Table 7.9 and indicates that there is very little time or distance variation as the results were similar.

Table 7.9 Sea Level Measurements

ABS	Observational Period	Maximum Observed	Minimum Observed	Range of Sea Level Variation
8	23 May to 30 Nov 2011	0.13	-0.15	0.28
10	19 May to 2 Nov 2011	0.42	-0.38	0.8
11	19 May to 2 Nov 2011	0.13	-0.29	0.42

7.5.2.3 Wave Climate and Storm Surges

In the Turkish EEZ, there are favourable conditions for the development of storm waves i.e. a large surface area, great depth and a weak irregularity of the coast. Throughout the summer the frequency of wave height of less than 1 m is 60 to 70%. In winter, the frequency of these waves is reduced to 20 to 30%. Wave height of 2 to 3 m is most often observed in winter with their frequency during this period reaching 20% whereas in the rest of the year this does not exceed 15%. Wave heights of 6 m or more are rare and their frequency does not exceed 1% (occurring in December to February). In the coastal regime, waving is very volatile and depends on the characteristics of a particular area. Storms are more common during the cold season, when their frequency is 10%. The frequency of calm periods in summer is up to 10 days (Table 7.10).

Table 7.10 Wave Height Frequency

Wave Height (m)	Winter	Spring	Summer	Autumn
Less than 1	27	45	70	42
1 to 2	43	40	24	42
2 to 3	20	12	5	12
3 to 6	9	3	1	4
6 to 11	1	0	0	0
Over 11	0	0	0	0

Short-term sea level variations are also associated with varying meteorological conditions and can result in localised sea level surges of up to 1 m.

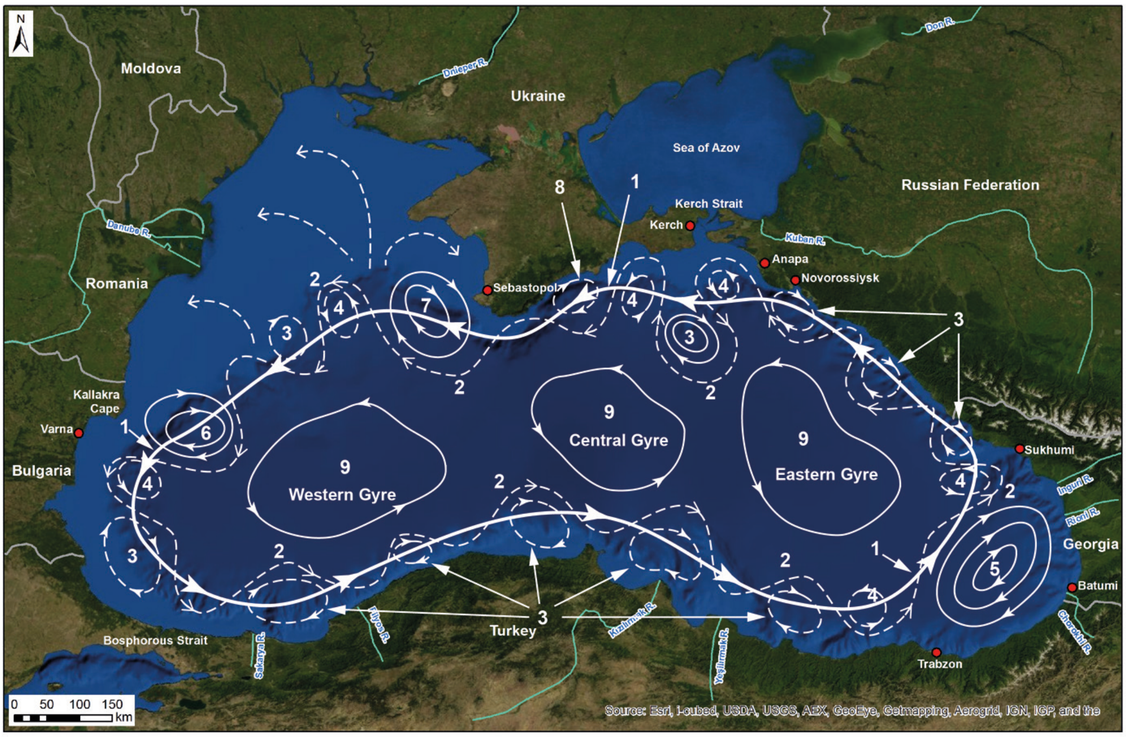
The frequency of storm surges in the Black Sea is lower than that in other regions of the world's oceans (Ref. 7.6). The gently sloping continental slope open to winds and waves is subject to storm surges and it is estimated that typical storm durations vary between 50 and 150 hours with an average duration of 95 hours (Ref. 7.7). Extreme storms have quite a short growth phase with an average duration of 61 hours. Hence, the typical storm pattern is characterised with fast growth, a rather durable energetic development phase and relatively prolonged decay.

7.5.2.4 Currents

The Main Black Sea Current (MBSC) affects the whole basin in one cyclonic (counter clockwise) circular motion. The Rim Current is a cyclonic current that follows the continental slope and is a prominent feature in the upper layer circulation in the Black Sea. A diagram of the MBSC is shown in Figure 7.12.

Current speeds in the core of the MBSC typically flow at 0.3 to 0.6 m/s depending on synoptic, seasonal and inter-annual variability. The upper layer waters of the Black Sea are characterised by a predominantly cyclonic, strongly time-dependent and spatially-structured basin wide circulation. The interior circulation comprises several sub-basin scale gyres; each of them involving a series of cyclonic eddies. They evolve continuously by interactions among each other, as well as with meanders, and filaments of the Rim Current. The Rim Current structure is accompanied by coastal-trapped waves with an embedded train of eddies and meanders propagating cyclonically around the basin (Ref. 7.7 and Ref. 7.8). Over the annual time scale, westward propagating Rossby waves further contribute complexity to the basin wide circulation system (Ref. 7.9).

Figure 7.12 Schematic Diagram of Currents in the Black Sea



Key:		
1: mean position of the cyclonic Rim Current jet current	**4:** cyclonic eddies	**7:** Sebastopol anticyclonic eddy
2: Rim Current meanders	**5:** Batumi anticyclonic eddy	**8:** Crimea anticyclonic eddy
3: anticyclonic coastal eddies	**6:** Kaliakra anticyclonic eddy	**9:** quasi-stationary cyclonic gyres

Source: Ref. 7.10

The most notable features of the circulation system, as schematically presented in Figure 7.12 include (Ref. 7.10):

- The meandering Rim Current system cyclonically encircling the basin;
- Two cyclonic sub-basin scale gyres comprising four or more gyres within the interior;
- The Bosphorus, Sakarya, Sinop, Kizilirmak, Batumi, Sukhumi, Caucasus, Kerch, Crimea, Sevastopol, Danube, Constantsa, and Kaliakra anticyclonic eddies on the coastal side of the Rim Current zone;
- Bifurcation of the Rim Current near the southern tip of the Crimea; one branch flowing south-westward along the topographic slope zone, and the other branch deflecting first north-westward into the shelf and then contributing to the southerly inner shelf current system;
- Convergence of these two branches of the original Rim Current system near the south-western coast; and
- Presence of a large anti-cyclonic eddy within the northern part of the north-western shelf.

According to the Acoustic Doppler Current Profiler measurements (Ref. 7.11), the Rim Current jet has a speed of 0.5 to 1 m/s within the upper layer, and about 0.1 to 0.2 m/s within the water depths of 150 to 300 m.

Within the Survey Area, mean current values were estimated to be close to 0.2 m/s near the seabed. This was supported by the review of primary ROV data as bottom currents were noticeably absent on all ROV footage of the Survey Area. In most cases, sediment flocculations disturbed from the seabed simply hang in the water column without appreciable movement (Ref. 7.12).

7.5.2.5 Water Temperature and Salinity

Seawater temperature results indicate that the temperature is almost constant near the seabed in the Survey Area and varied between 9.10 and 9.12 ^{o}C along the measurement points (Ref. 7.1). In the surface layer, temperatures ranged from 21.2 to 22.7°C in the surface layer while showing a sharp decrease to 8 to 9°C at depths from 15 to 20 m. These values did not exceed 8.5°C in the anoxic layer beginning at a depth of 80 to 100 m and showed a slight increase up 9.1°C at depths of about 2,000 m (Ref. 7.1).

Salinity values are constant at 18 practical salinity units (PSU) to a depth of 30 m following which a pronounced increase to values of 21 PSU at depths of 80 to 100 m. A smoother increase in salinity is observed from a depth of 200 to 1000 m. Salinity values on the seabed were on average 22 PSU (Ref. 7.1).

7.5.2.6 Water Density

During the year, water density changes as a function of salinity and temperature. The Black Sea stratification within the upper 100 m varies up to a density (Sigma-t (σt)) of approximately 5 kilograms per cubic metre (kg/m^3). The pycnocline corresponding to the density (σt) of 16.2 kg/m^3 is observed at 150 m water depth within the interior cyclonic zone and may extend to 200 m within coastal anticyclones. The intermediate and deep water masses below a permanent halocline (a strong, vertical salinity gradient) at water depths of 100 to 150 m possess almost vertically uniform characteristics defined by temperatures of approximately 9 ^{o}C, salinity of 22 PSU and density (σt) of 17.0 kg /m^3 (Ref. 7.13). The abyssal plain possesses almost vertically uniform characteristics below 200 m within the range of values of temperature, salinity and density values of approximately of 8.9 to 9.1 ^{o}C, 22 to 22.5 PSU, and 17 to 17.3 kg/m^3 respectively. The deepest part of the water column involves homogeneous water mass formed by convective mixing due to the bottom geothermal heat flux during the last several thousands of years (Ref. 7.14).

7.5.2.7 Water Quality

The water quality of the Black Sea, particularly the western part, declined significantly during the 1970s due to excessive nutrient enrichment from river discharge. Currently, lower levels of nutrient loading are being reported. However, values are still considerably higher than those observed before the 1960s (Ref. 7.9).

The saline stratification of the Black Sea, combined with its significant maximum depths, generates conditions that are absent of oxygen (anoxic). The Black Sea is therefore considered the world's largest anoxic basin. Waters with low oxygen (hypoxic) or entirely anoxic conditions are typically incapable of sustaining permanent populations of species dependant on aerobic respiration i.e. respiration requiring oxygen. Consequently, the potential for significant marine life occurring at depths of greater than approximately 150 m within the Black Sea is limited. Any marine life is also likely to be limited to those organisms capable of anaerobic respiration[1]. Anaerobic respiration typically produces hydrogen sulphide (H_2S) and Methane (CH_4) as a by-product. Concentrations of H_2S are known to increase with depth in the Black Sea. Such conditions are prohibitive to many life forms whilst creating conditions conducive to the preservation of organic and inorganic materials. These conditions are also the reason for the high preservation potential of Cultural Heritage Objects (CHOs) (Ref. 7.9) as discussed in **Chapter 10 Cultural Heritage**.

Understanding the characteristics of marine water quality in the Black Sea requires an appreciation of the importance of stratification with depth. The upper sea layer experiences seasonal and annual variation in hydro-physical and hydro-chemical characteristics under the influence of external climatic factors. Its lower boundary is a deep pycnocline, below which influence of the external factors does not normally extend and hydro-chemical conditions are relatively stable (Ref. 7.1).

The survey was conducted in autumn 2011 to assess hydro-chemical and water contamination and samples were collected at 15 locations in the Survey Area (Figure 7.1 to Figure 7.7). The survey results indicated the following:

- Suspended solids concentrations were relatively low when compared to historical data from the Black Sea (Ref. 7.1);
- The concentration of inorganic pollutants and organochlorine pesticides was below the detection limit; and
- Relatively high concentrations[2] of mineral oil, anionic surfactants and phenols were present indicating anthropogenic impact on water quality.

The Following information is taken from survey results gathered from 2011 surveys (Ref. 7.1):

Oxygen

Recorded dissolved oxygen concentrations varied from 8.3 to 9.8 milligrams per cubic decimeter mg/dm^3 at the surface (0 m). The values varied between 9.0 to 9.82 mg/dm^3 at 40 to 50 m falling to 0.1 to 0.2 mg/dm^3 at water depths of 80 to 100 m. Below 150 to 200 m, conditions became anoxic (devoid of oxygen) (Ref. 7.1).

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[1] Anaerobic respiration is respiration without oxygen, such as by chemosynthetic life instead of photosynthetic life.

[2] Assessed using Russian standards. "*Water quality standards for fishery water bodies, including maximum permissible concentrations of harmful substances for fishery water bodies*". Approved by the Order of the Federal Agency for Fisheries No. 20 of January 18, 2010.

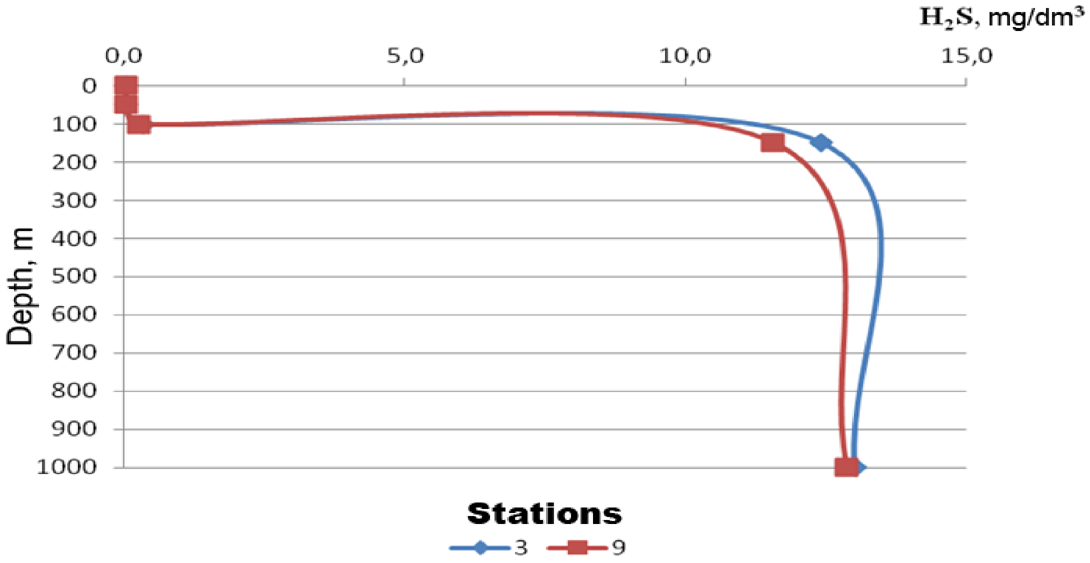
Hydrogen Sulphide

The content of H_2S varied from its absence on the surface (<0.05 mg/dm^3) to a gradual rise to 11.4 to 12.9 mg/dm^3 near the seabed. The sharp increase in the values of H_2S began at a depth of approximately 100 to 150 m, where the values averaged 10.5 mg/dm^3 (Figure 7.13) (Ref. 7.1).

pH

The values of pH ranged from 7.14 to 8.39. The pH was greater at 30 to 40 m water depth than at the surface at most stations with a decrease in pH with depth noted at all stations. The sharp decrease in the pH values associated with the anoxic layer can be seen in Figure 7.14.

Figure 7.13 The Distribution of Hydrogen Sulphide (mg/dm^3) in the Water Column



Organic Matter

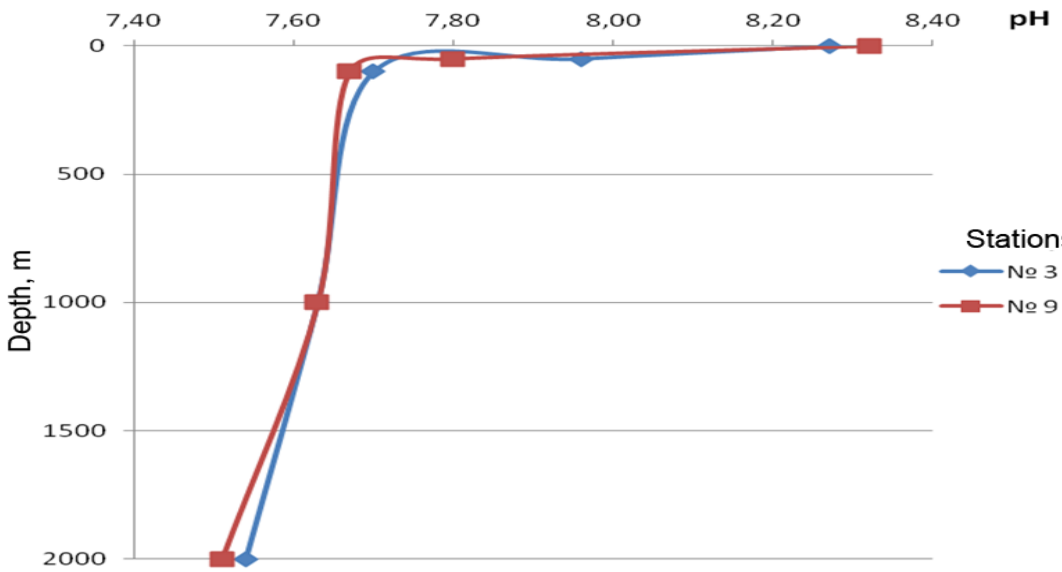
BOD

In autumn 2011, measurements of the biochemical oxygen demand (BOD5) were undertaken to provide indirect measurements of organic matter in the water (Ref. 7.1). BOD5 values ranged from 0.5 to 1.9 mg O_2/dm^3. The lowest values in the surface layer (0 m) were recorded at three stations (1, 9, 11) at below the detection limit (<0.5 mg O_2/dm^3). The highest values were observed above the pycnocline at 1.9 mg O_2/dm^3 and fell to between 0.8 to 1.1 mg O_2/dm^3 at approximately 2,000 m water depth.

Nitrogen

The concentrations of nitrate nitrogen were below detection limit (<5 µg/dm^3) at almost all stations and at most depths sampled. The exceptions were Station 3 (9 µg/dm^3 at 49 m depth), Station 6, (11 µg/dm^3 at 0 m) and Station 9 (6 and 7 µg/dm^3 at 150 m and 200 m) (Ref. 7.1).

Figure 7.14 Distribution of pH in the Water Column



Nitrite nitrogen (N-NO_2) values were generally low at the surface (0 m) and below detection limit (<0.5 µg/dm^3) at six stations (1, 2, 4, 5, 6, 9). The values increased at 50 to 100 m water depth and ranged from 0.6 to 6.3 µg/dm^3. These values decreased to 0.6 to 2.4 µg/dm^3 depths of 100 to 120 m (Ref. 7.1).

Ammonia nitrogen (N-NH_4^+) ranged from 19 to 66 µg/dm^3 at 0 m water depth with an average concentration of 40 µg/dm^3. Most stations showed an increase in the layer above the pycnocline (above 150 m water depth) to an average of 53 µg/dm^3. Ammonia nitrogen averaged 100 µg/dm^3 below 200 m water depth. The concentration reached values from 558 to 913 µg/dm^3 at a depth of approximately 2,000 m.

The content of organic nitrogen (N_{org}) throughout the water column was below the detection limit (<250 µg/dm^3). Total nitrogen (N_{tot}) was below the detection limit (<250 µg/dm^3) at the surface (0 m) and below 200 m. High values were recorded only at depths of 2,000 m (from 773 to 1096 µg/dm^3).

Phosphate phosphorus (P-PO_4) was practically absent (<5 µg/dm^3) at the surface (0 m) with the exception of two stations (9, 15). The values increased between 6 and 14 µg/dm^3 between 50 to 150 m water depth with the highest concentrations recorded below 200 m water depth of between 108 and 201 µg/dm^3.

Organic phosphorus values ranged between 7 to 64 µg/dm^3 in the surface layer and increased to between 8 to 73 µg/dm^3 with an average grade of 35 µg/dm^3 at a depth of 40 to 50 m. Values reached an average of 343 µg/dm^3 below 200 m and increased to an average of 618 µg/dm^3 at 2,000 m depths. Total phosphorus ranged from 8 to 69 µg/dm^3, with an average of 53 µg/dm^3 in the surface (0 m). These values increased to an average of 40 µg/dm^3 around 50 to 150 m water depth and 476 µg/dm^3 below 200 m. The average values recorded at 2,000 m water depth were 835 µg/dm^3.

Sea Water Contamination

Lead concentrations were mostly below the limit of detection (<0.002 mg/dm^3) or exceeded it slightly. Values of 0.032 mg/dm^3 and 0.005 mg/dm^3 were recorded at a depth of 35 m at Station 11 and a depth of 1,970 m at Station 14. The content of dissolved iron in seawater was slightly above detection limits and ranged from <0.01 to 0.039 mg/dm^3, with an average of 0.024 mg/dm^3. The manganese content ranged from 0.0017 to 0.240 mg/dm^3, with an average grade of 0.11 mg/dm^3. There was an increase in concentration with depth starting from the depths of 100-110 m. The highest concentrations of manganese were observed at depths of around 2,000 m at Stations 3, 9 and 14. The distribution of manganese in the water layer was uniform throughout the Survey Area (Ref. 7.1).

Concentrations of mercury, cadmium, copper, chromium, selenium, arsenic, molybdenum and cadmium were below the detection limit in all samples. The content of nickel and zinc were also below the detection limit in all samples, except for the sample obtained in the bottom layer at Station 14 (Ref. 7.1).

The content of petroleum products in the waters of the Survey Area was quite high and ranged from <0.02 to 0.73 mg/dm^3, with an average of 0.34 mg/dm^3. The content of anionic surfactants (AS) showed levels ranging between from 0.15 to 0.59 mg/dm^3 (Ref. 7.1). Arsenic concentration decreased to an average of 0.19 to 0.2 mg/dm^3 with increasing depth but with a depth of 150 to 200 m once again increased to 0.25 to 0.4 mg/dm^3. The phenol content ranged from 0.002 to 0.015 mg/dm^3 (Ref. 7.1).

As for pesticides, the content of dichlorodiphenyltrichloroethane (DDT) and its breakdown products in the Survey Area waters throughout the water column was below the detection limit (<0.001 µg/dm^3) and hexachlorocyclohexane (HCH) pesticides were also not detected (<0.001 µg/dm^3) (Ref. 7.1).

The following conclusions can be drawn from the chemical properties tested in the Survey Area (Ref. 7.1):

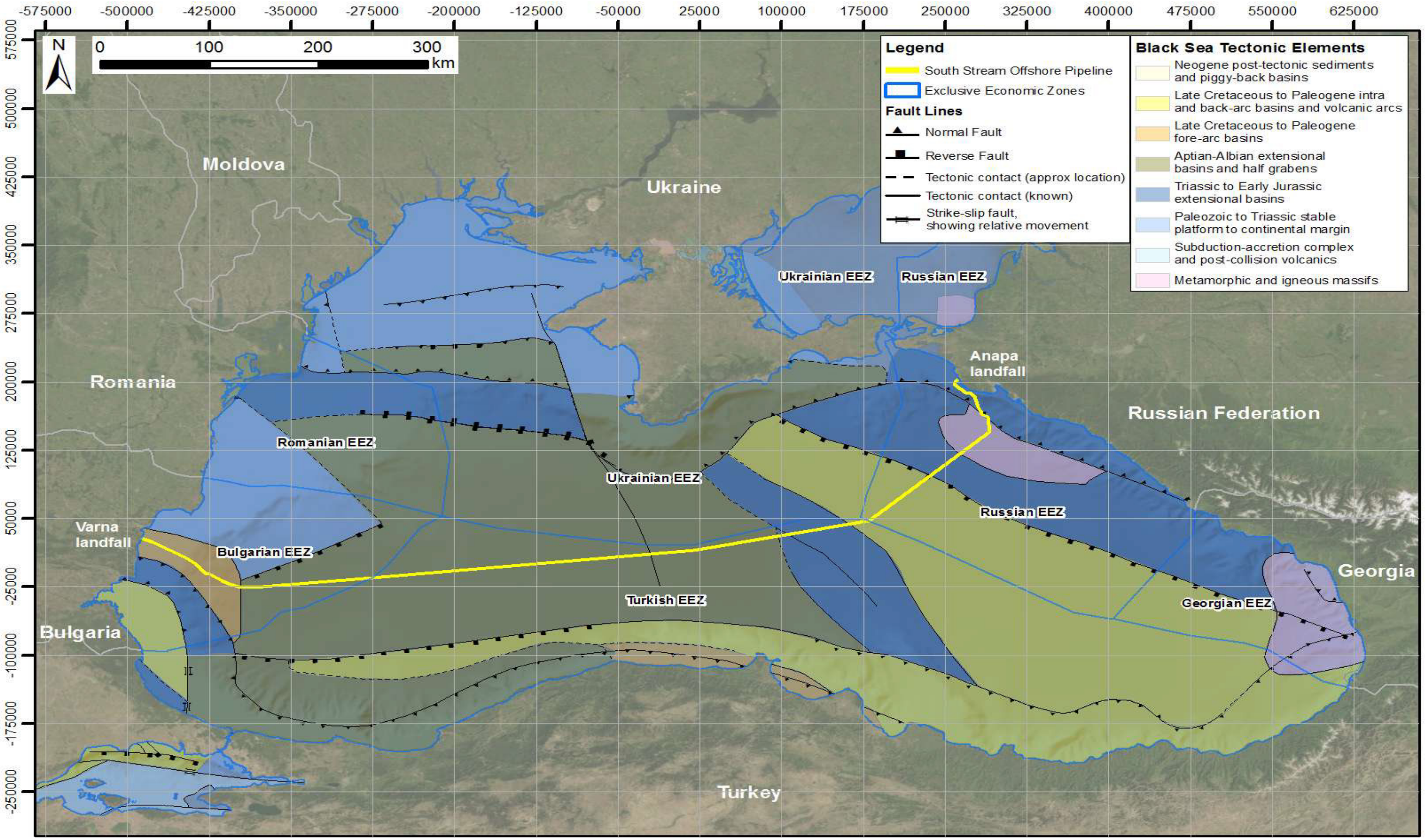
- The concentration of inorganic pollutants in most samples was below the detection limit which would indicate un-impacted environmental conditions of marine waters;
- Relatively high concentrations of mineral oil, anionic surfactants and phenols were observed which would indicates adverse anthropogenic impact on the waters of the Black Sea; and
- Organochlorine pesticides – DDT and HCH – were below the detection limit of the analysis methods used.

7.5.3 Geophysical Environment

7.5.3.1 Tectonic Settling and Geology

The Black Sea abyssal plain is framed by folded structures to the north, northeast, south, and southwest; to the northwest it forms an elevated platform, which is part of the Black Sea shelf between the Balkan Peninsula coast and the Crimea. The tectonic map of the Black Sea Region is shown in Figure 7.15 (Ref. 7.15).

Figure 7.15 Tectonic Map of the Black Sea Region



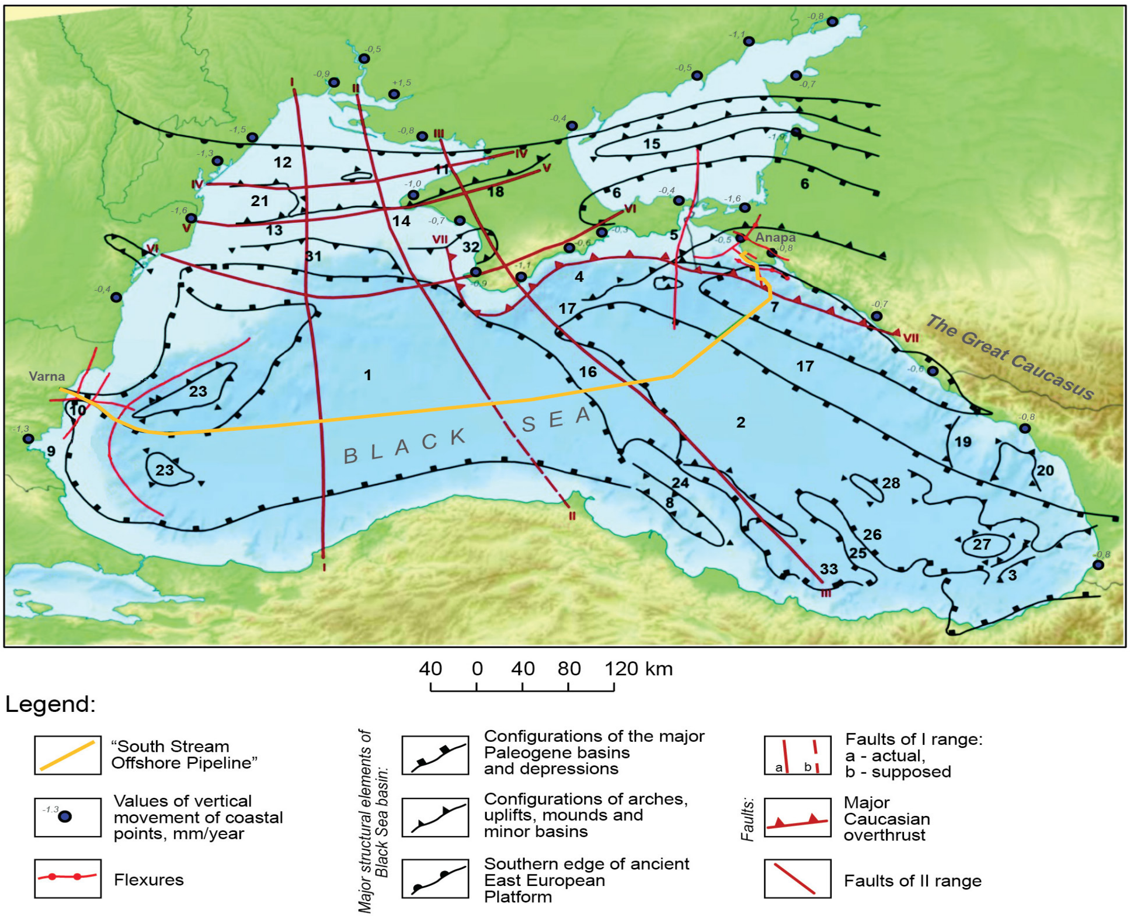
Source: Ref. 7.15

7.5.3.2 Seismicity

The seismic activity in the Black Sea is relatively weak and in its central parts it is negligible. On the coast of Turkey however moderate earthquakes have been recorded. There are two important seismic belts around the Black Sea: northern Turkey (the North Anatolian fault) and the Caucasus region (Ref. 7.16).

There are several hundred meters of Mesozoic sediments within the Eastern Black Sea abyssal plain (Ref. 7.15). These sediments are faulted and with the bedrock they form inclined blocks that underlay almost the entire basin. Seismic data indicates that Cenozoic sediments in the Eastern Black Sea basin are almost undisturbed by fault dislocations (Figure 7.16).

Figure 7.16 Black Sea Structural and Tectonic Classification Scheme



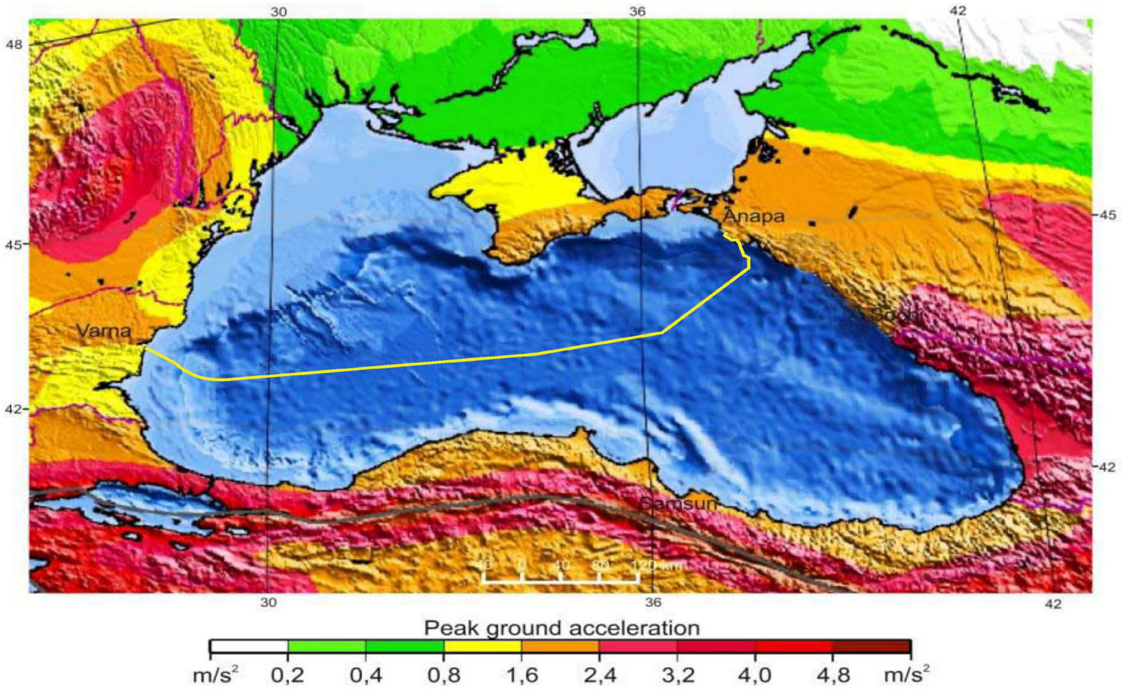
Source: Ref. 7.16

A baseline seismicity assessment based on a probabilistic analysis was conducted as part of the seismic hazard estimation. The results showed that the 1,000 years recurrence interval peak ground accelerations change between Anapa to Varna from 0.33 to 0.28g m/s^2. Other features associated with geohazards include mud volcanoes and tension fractures (Ref. 7.1).

7.5.3.3 Geohazards

Figure 7.17 shows seismic hazard map developed within the Global Seismic Hazard Assessment Project (GSHAP) for the Black Sea region (Ref. 7.17). The peak horizontal acceleration (PGA)[3] values are 0.10g m/s^2 or less within the abyssal plain for recurrence interval of 1,000 years.

Figure 7.17 Fragment of Seismic Hazard Map, Constructed within the International Project GSHAP, for the Areas Surrounding the Black Sea region



Note: the South Stream Offshore Pipeline is shown in yellow. **Source**: Ref. 7.17

Mud Volcanoes

Mud volcanism is a manifestation of the release of natural gas on the seafloor from the deep sedimentary strata. Mud volcanoes of two main types are distinguished in the Black Sea: those along the periphery of the basin (Bulgaria, Kerch-Taman region) and those associated with fluidised sediment flow connected to ruptures on domes of gently sloping symmetrical anticlines in the central part of the Black Sea. Natural gas seeps on the bottom of the Black Sea are widespread on the continental margins and abyssal plain. Gas seeps on the abyssal plain are mainly associated with biogenic methane and are related to mud volcanoes and tectonic faults. A characteristic feature of some areas of the slope of the Black Sea (Bulgaria, Ukraine, and Turkey) is a high gas saturation of recent sediments and gas releases in the form of plumes (Figure 7.18).

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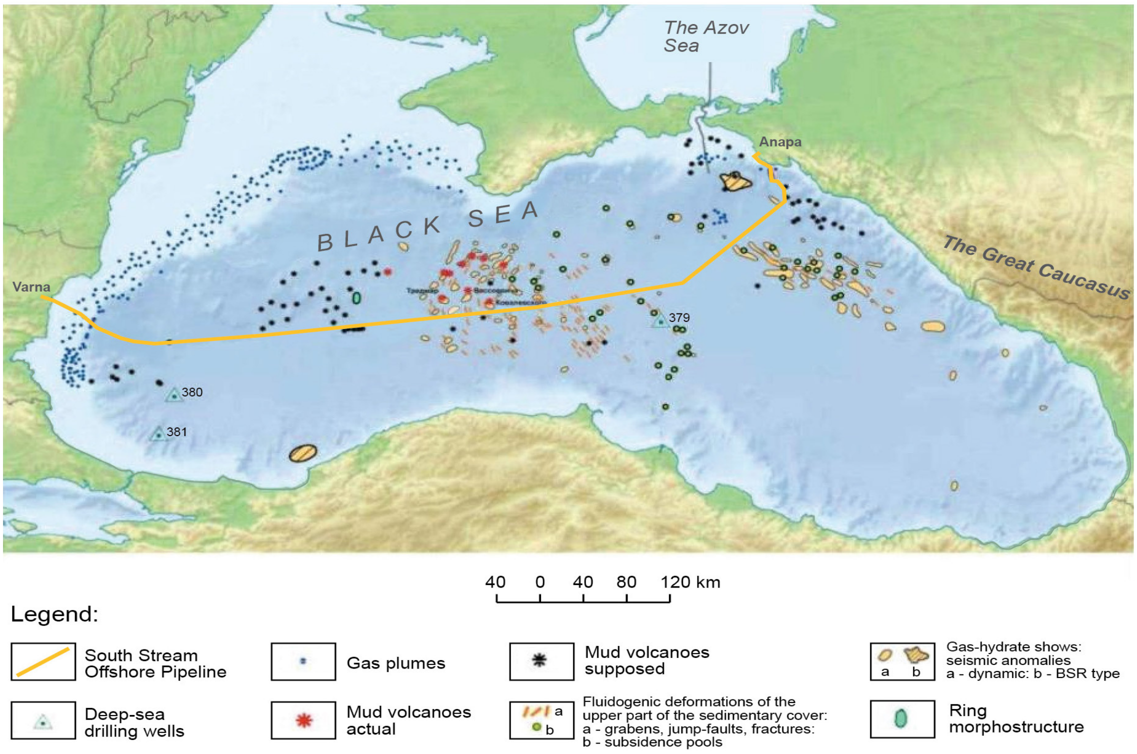
[3] A measure of earthquake acceleration on the ground

Figure 7.18 Mud Volcanism Features in the Black Sea



Source: Ref. 7.1

During geotechnical surveys in 2011, the abyssal plain revealed a significant number of deformations related to the rise of hydrocarbon fluids. No mud volcanoes were observed in the Survey Area (Ref. 7.1). Rather they are represented by dislocations, small faults, small subsidence troughs and craters on the tops of very gentle anticlinal uplifts. The area of deformation distribution is the same as the area of mud volcanoes, gas-saturated sediments and gas-hydrates. Development of landslide processes in the abyssal plain has not been detected and is not expected due to minor slopes of the seabed surface (Ref. 7.1).

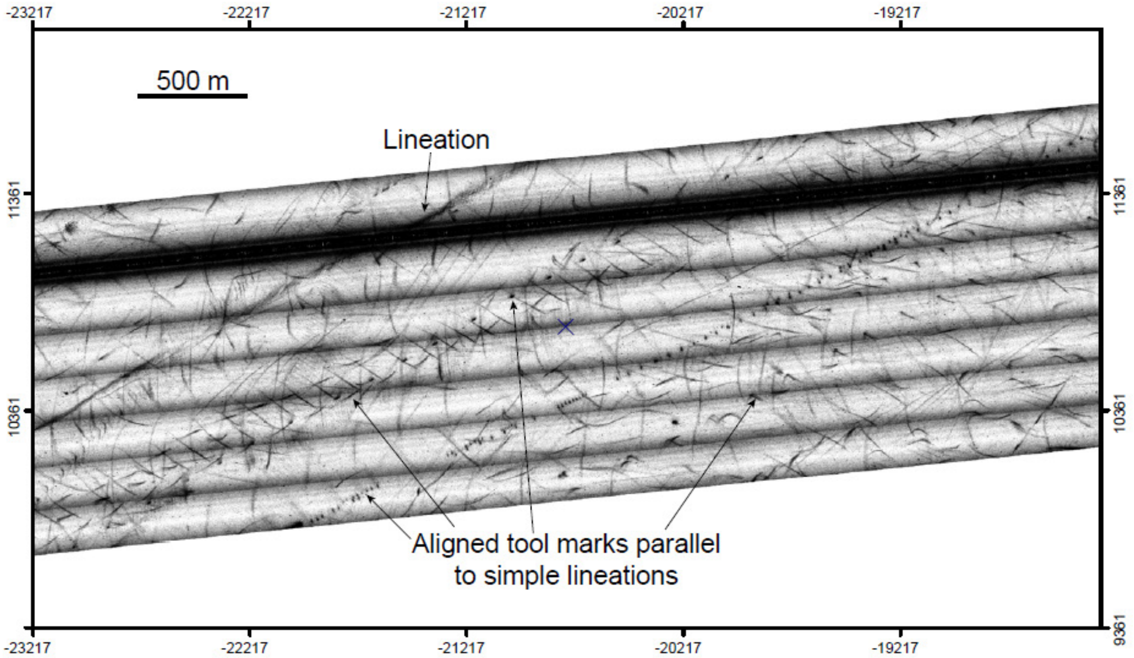
7.5.3.4 Geomorphology

During 2011 geotechnical surveys (Ref. 7.1), the deepest, eastern part of the abyssal plain was observed to lack any large-scale features but, side scan sonar (SSS) data showed abundant linear and irregular fine-scale markings (Figure 7.19), interpreted as marks caused by objects such as trees carried along by bottom currents and gouging the seabed (Ref. 7.12).

They mainly trend northeast to southwest and SSS data also showed numerous small high backscatter targets that are typically scattered randomly but can on occasion form aggregated groups (Figure 7.20).

Analysis of the 2011 survey data (Ref. 7.12) shows that the seabed in the west of the Survey Area rises gently onto the flank of the channel levee area. SSS data also showed the lower part of the levee complex flank to be covered by sediment waves.

Figure 7.19 Side Scan Sonar Image of Survey Area Showing Marks



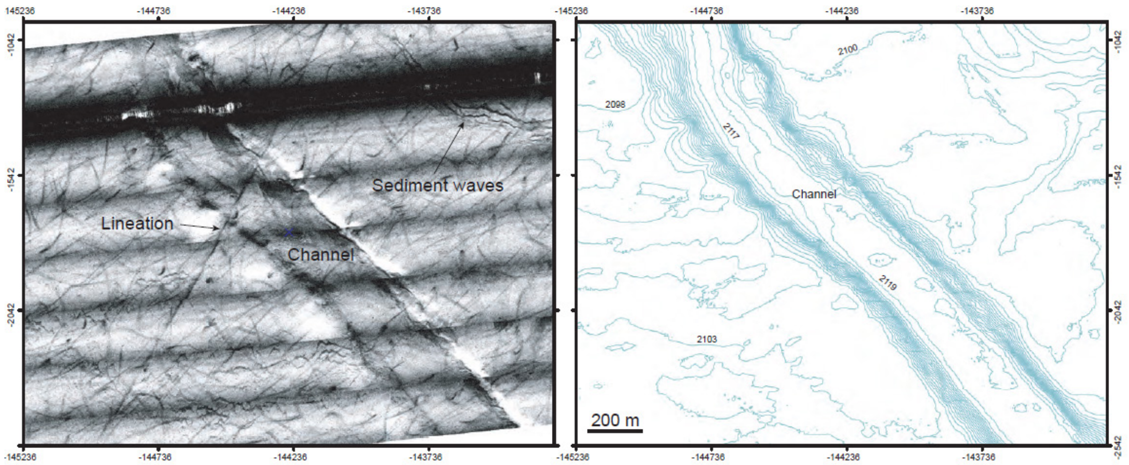
Note: that these features have no bathymetric expression, suggesting that they are relatively old features buried by later sedimentation.

Source: Ref. 7.12

These are oriented approximately east-west, perpendicular to the adjacent channels and to the levee slope. They are interpreted as sediment waves built by unconfined turbidity currents. Their location is consistent with turbidity flows moving south in the deep to the east of the levee, but pinned against the levee flank by Coriolis force. This interpretation is also supported by the occurrence of backscatter banding, oriented almost north to south that is the typical signature of sediment deposited by turbidity currents (Ref. 7.12).

Six channels crossing the Survey Area can be identified in bathymetry data (Ref. 7.12). Most of these have rather indistinct signatures on SSS data and are clearly partly buried. They can thus be inferred to be inactive (not subject to sediment flows, turbidity currents, moving through the canyon), although this needs to be confirmed by analysis of sediment cores. The easternmost channel, however, has a relatively sharp appearance on bathymetry and SSS data, as well as a clear backscatter contrast between channel floor and flanking levee (Figure 7.21). It is thus inferred to be the youngest channel in the overall channel levee complex, although recent activity cannot be confirmed or ruled out. This channel shows flanking features that could be interpreted either as terraces, or as channel wall failures. However, the position of these features, just downstream of bends in the channel and on the inside channel wall, supports their interpretation as terraces (Ref. 7.12).

Figure 7.20 Side Scan Sonar Image (left) and Bathymetry (right) showing part of a channel on the Distal Danube fan



Source: Ref. 7.12

7.5.3.5 Marine Sediments

Sedimentation in the abyssal plain of the Black Sea is very slow and consists of clay-silt size[4] planktonic detritus (mainly consisting of calcium carbonate and organic matter) mixed with minor quantities of clay size terrigenous sediments. Given the organic nature of the majority of the detritus, organic decay ooze can often be found, often separated from the inorganic fraction of the sediment and forming discreet layers within the sediment column (Ref. 7.1). The upper 1 m of the seabed within the Turkish Sector is summarised as follows (Ref. 7.1):

- Uppermost layer is approximately 0.3 m thick and comprising the remains of phytoplankton (coccolith) deposits and greenish-grey clay;
- Intermediate layer, approximately 0.4 m thick and comprising dark-grey organic rich decay ooze, jelly-like in substance; and
- Lower layer approximately 0.3 m thick and comprising alternative layers of ooze, with silt and sand, with colours ranging from grey and browns to black spots (due to the presence of iron sulphite aggregates).

The sediments can be divided into shallow and deep water sediments compositional-genetic type classification. The deep-water sediments in the Black Sea are listed below and shown on Figure 7.22

- Carbonate-free terrigenous sediments;
- Carbonate-poor organogenic- terrigenous muds;

[4] Particle size refers to the diameter of individual grains of sediment. In this case, the clay to silt size range is between 0.0039 mm to 0.0625 mm.

- Carbonate-poor, organogenic-terrigenous, finely dispersed;
- Carbonate-bearing, organogenic-terrigenous, finely dispersed Coccolith muds;
- Carbonate-rich (locally carbonate-bearing), finely dispersed Coccolith muds rich in organic matter; and
- Modern sediments of considerable diversity with predominance of carbon-poor organogenic-terrigenic muds.

Sediments collected in 2011 at Stations 3, 6, 9 and 11 (Figure 7.1) also included testing for grain size, organic content and pH. The results of the fractional size analysis were converted into four key factions: gravel (10 to 1 mm), sand (1 to 0.1 mm), silt (0.1 to 0.01 mm) and pelite (less than 0.01 mm) (Ref. 7.1). A diagram showing the distribution of particle size of sediments on the main fractions is shown in Figure 7.23.

Sediment Contamination

Surveys in the area have identified the presence of contaminants in the marine sediments including petroleum hydrocarbons, phenols, anionic surfactants and heavy metals. Concentrations were typically highest near the coast, particularly in the vicinity of the main towns. In addition, some heavy metals (e.g. iron, manganese) are naturally present in relatively high concentrations in the marine sediments in deep waters owing to the prevailing redox environment. The level of seabed pollution depends on many factors including the lithological type of the deposit, particle sizes, the depth of the sea, the properties of the polluting substances (pollutants) and the level of their arrival from the coast, hydrological conditions, the system of currents, etc.

The top layer of sediment (about 0.3 m) is of interest since the pipelines will be placed directly on top of this layer. Testing for water content, density, Atterberg limits (tests which identify the consistency and behaviour of sediment), particle size distribution, organic matter and carbonate content were conducted for classification of properties and sediments at various sampling locations in the Turkish EEZ. Sediments in the Survey Area are considered generally uncontaminated, though elevated levels[5] of anionic surfactants, cadmium (Cd), and in one sample, nickel (Ni) were observed (Ref. 7.1). However, any elevated levels of heavy metal concentrations observed in samples from this depth are not likely to have a significant impact on the ecosystem of the Black Sea (Ref. 7.1). The surveys (Ref. 7.1) also indicated that petroleum hydrocarbon concentrations were at levels under the target levels[5] (Ref. 7.19) and that phenol concentrations at all stations were below the detection limit (<0.1 milligrams per kilogram (mg / kg)). The following conclusions were drawn from the sediment analysis:

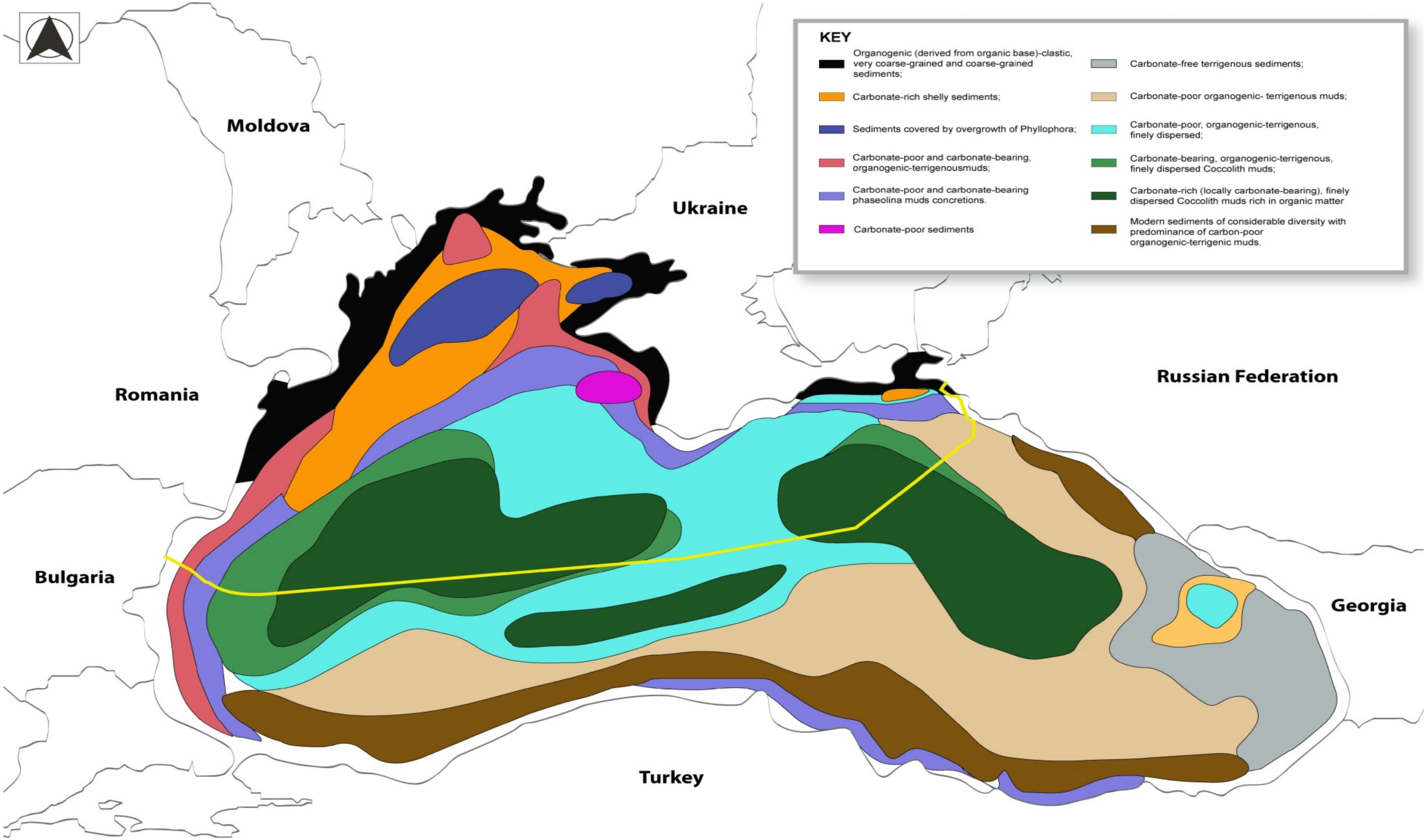
- Two hundred and thirty four (234) samples were classified as clayey sediments and the remainder of the samples (12 samples) were classified as sandy sediments;
- Considerable organic content (6.8 to 66.2%) was revealed in the samples;

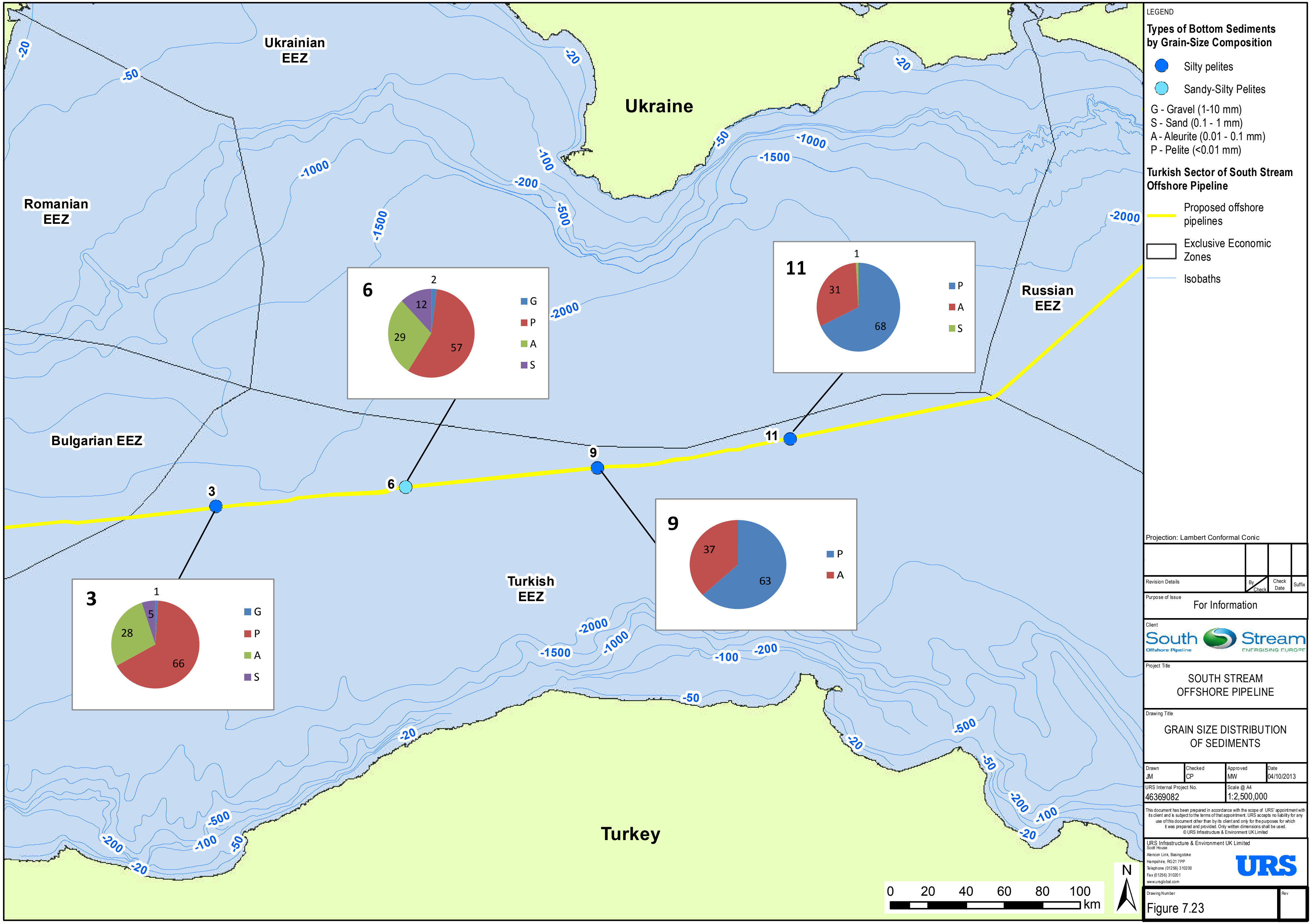
[5] Dutch Target and Intervention Values, 2000 - Circular on target values and intervention values for soil remediation. Sediment analysis was conducted by Russian laboratories. As the content of pollutants in bottom sediments was not regulated by Russian documentation, the Dutch Standards were used as a reference document.

- Approximately 60% of the sediments belong to the OH group (organic clays with high plasticity), 25% – to CH group (clayey sediments with high plasticity) and the rest belonging to groups SM (silty sand) and ML (silt); classified in accordance with American Society for Testing and Materials (ASTM);
- Approximately 80% of the tested sediments have alkaline properties (pH>7) and the remaining 20% have acid properties (pH<7);
- The main part of the tested sediments appeared to be slightly over consolidated with over consolidation ratio (OCR) varied between 0.4 and 2.7; and
- The sediments have high deformability, low strength and low permeability.

Sediment samples collected at four locations in 2011 revealed that the majority consist of clayey fine grained sediments (Ref. 7.1), with the clay fraction of all samples being greater than 57% which is similar to that observed from the 246 samples taken above in the same area (within the Survey Area). The geochemical assessment was conducted on the samples and results are presented in Figure 7.24. These results are in line with previously published sediment sampling results in the Black Sea (Ref. 7.9).

Figure 7.22 Generic Types of Modern Black Sea Sediments





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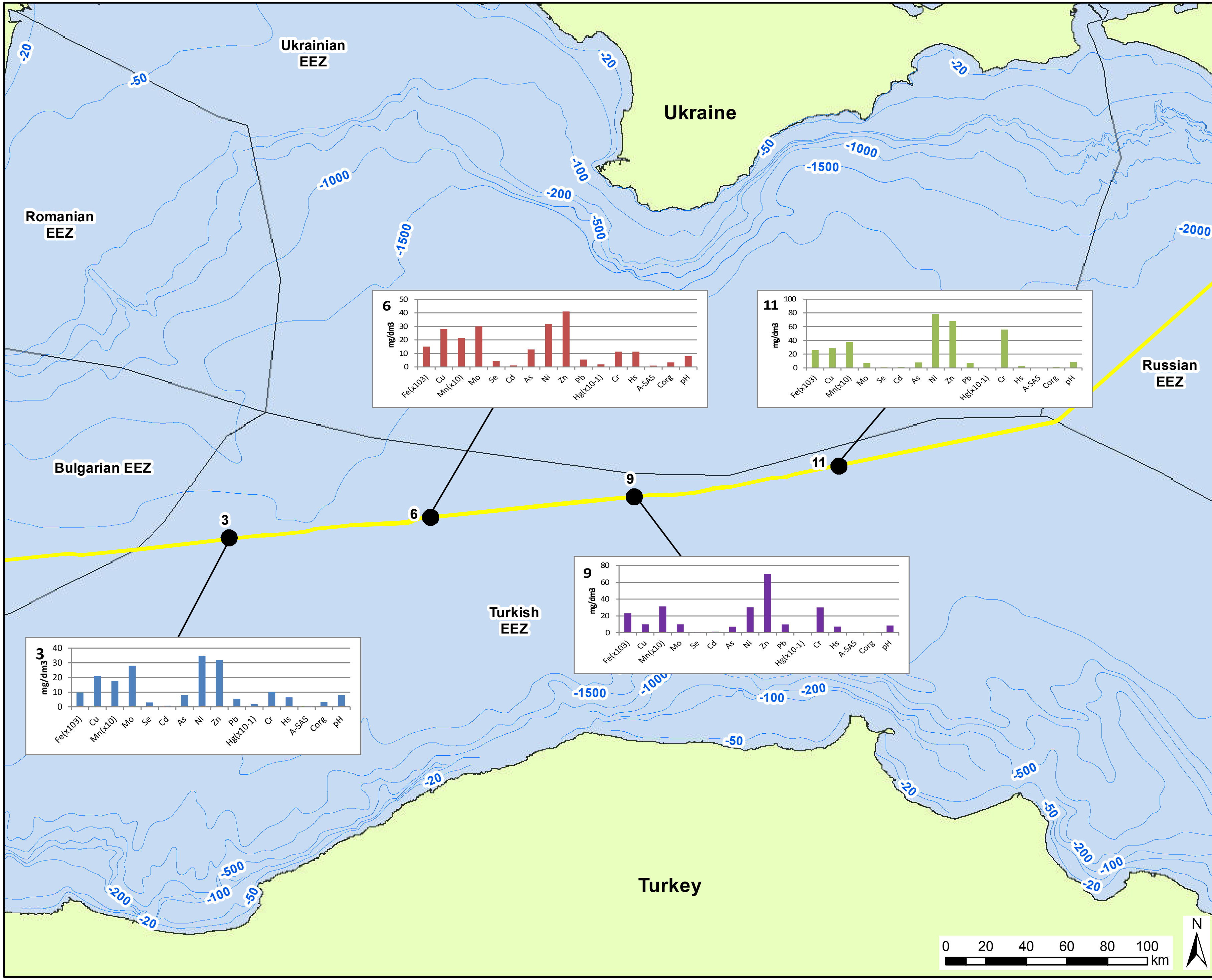

LEGEND

Sampling stations and their numbers

Content of Iron (Fe), Copper (Cu), Manganese (Mn), Molybdenum (Mo), Selenium (Se), Cadmium (Cd), Arsenic (As), Nickel (Ni), Zinc (Zn), Lead (Pb), Mercury (Hg), Chrome (Cr), Petroleum Hydrocarbons (HC), Anion-Active Surface-Active Substances (A_SAS), Organic Carbon (Corg), mg/kg, pH value(bottom sediments)*

* values not shown at diagrams were under detection limit

Turkish Sector of South Stream Offshore Pipeline

Proposed offshore pipelines

Exclusive Economic Zones

Isobaths

Projection: Lambert Conformal Conic

Revision Details	By / Check	Check Date	Suffix

Purpose of Issue: For Information

Client: South Stream Offshore Pipeline — ENERGISING EUROPE

Project Title: SOUTH STREAM OFFSHORE PIPELINE

Drawing Title: SEDIMENT CHEMICAL CONCENTRATIONS

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Drawing Number: Figure 7.24 | Rev

Plot Date: 26 Feb 2014
File Name: I:\5004 - Information Systems\46369082_South_Stream\MXDs\Report Maps - Turkey\Turkey ESIA\Chapter 7\Figure 7.24 Sediment Chemical Concentrations.mxd

7.6 Impact Assessment

As discussed in Section 7.2, there is no impact assessment conducted for the receptors of the physical environment.

7.7 Unplanned Events

The oil spill modelling summarised in **Chapter 13 Unplanned Events** states that the fuels in question, if spilt, would evaporate to a significant degree with the remainder being naturally dispersed by wave action within a few days of being spilled. As such, impacts to water quality are expected to be short-term and **Not Significant**. No other physical receptors are likely to be impacted by an unplanned event.

7.8 Cumulative Impacts Assessment

Given that there are no residual impacts on physical receptors, there is no scope for cumulative impacts and the physical environment was not considered in **Chapter 14 Cumulative Impact Assessment**.

7.9 Conclusions

The baseline conditions in the Black Sea have recorded increased salinity and H_2S concentrations with depth. Anoxic conditions are observed below 150 to 200 m water depth. Water quality samples recorded relatively low concentrations of suspended solids and concentrations of inorganic pollutants, and organochlorine pesticides were below detection limits. However, high concentrations of mineral oil, anionic surfactants and phenols were present indicating anthropogenic impact on water quality.

The Black Sea neighbouring countries are seismically active, however, faults within the abyssal plain of the Turkish Sector are almost undisturbed by fault dislocations. Sediments in the Survey Area are predominately clayey and contain a considerable amount of organic content (6.8 to 66.2%). Sediments were predominately uncontaminated although elevated levels of anionic surfactants, cadmium (Cd), and nickel (Ni) were observed in some samples. However, any elevated levels of heavy metal concentrations observed in samples from this depth are not likely to have significant impacts on the ecosystem of the Black Sea.

In summary, it is considered that all physical receptors in the Turkish EEZ can be scoped out of any impact assessment. Given the scope of the Project activities and design controls, there is unlikely to be an impact on sediment quality, geological and hydrodynamic processes, air quality and water quality.

Indirect impacts of water quality on the marine ecological environment are discussed in **Chapter 8 Biological Environment**.

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