Appendix 19.3: Terrestrial and Marine Geohazards

URS-EIA-REP-204635

Overview

Geohazards are known to exist in the Black Sea region.

As described in **Chapter 5 Project Description**, design hazards have been identified and assessed using internationally recognized tools throughout the FEED process (Ref. 19.6, 19.7, 19.8). This has included undertaking detailed route selection studies, as described in **Chapter 4 Analysis of Alternatives**, to select the Pipeline route taking into account geohazards.

As described in **Chapter 4 Analysis of Alternatives** and **Chapter 5 Project Description**, the Pipeline route, design and the proposed construction methodology have taken into consideration the potential geohazards, mitigating the risks as far as is practicable.

As described in **Chapter 5 Project Description**, regular monitoring and inspection of the Pipeline will be undertaken throughout the Operational Phase. This will enable any changes to the local environment, particularly those relating to seismic and geomorphological processes, to be identified and managed.

Terrestrial Geohazards

Geohazards in the Terrestrial Study Area (landfall section) include slope stability, seismic activity, coastal and fluvial erosion and flooding.

Active orogenic faulting is occurring in the Black Sea region (**Chapter 7 Physical and Geophyscial Environment**). Geohazards associated with seismic and fault movement activity includes deformation of slopes (including landsliding and collapse of cliffs or slopes). Additionally, seismic activity can affect infrastructure and may cause structural failures; i.e. seismic hazards include strong ground motions due to peak ground acceleration and dislocation of ground (horizontally and / or vertically) due to movement along faults.

Slope instability and gravity-induced landsliding is a potential geohazard within the Terrestrial Study Area (landfall section). As described in **Chapter 4 Analysis of Alternatives**, the terrestrial Pipeline route was selected taking into account local topography as well as geotechnical and seismic constraints.

The pipeline route crosses the Marfovsky Fault zone. This fault is considered to be active (Ref. 19.7). As described in **Chapter 5 Project Description**, the fault will be crossed using traditional open-cut techniques. However, to minimise the effect of potential displacement from seismic activity, each pipeline will be laid in an enlarged trench approximately 200 m long that will have a bottom trench width approximately 5 m wide. The depth of the excavated trench shall be at least 3 m below the lowest point of the pipeline and the cover depth above the top of the pipeline will be approximately 1.5 m. The pipelines in the fault section will be laid on a bed of sand and backfilled with loose sand rather than the previously excavated soils. The combination of the wider trench and backfilling with loose sand allows the pipelines to move in a lateral direction reduce the risk of movement on the Marfovsky Fault affecting pipeline integrity.

Due to the steepness of the coastal topography and the presence of rock at surface, open-cut installation of the onshore pipeline across the sea cliffs is not feasible. As described in **Chapter 4 Analysis of Alternatives** and **Chapter 5 Project Description**, the trenchless technique of microtunnelling has therefore been selected as the construction technique for the shore crossing. Microtunnelling helps mitigate the geomorphological and geotechnical risks associated with the near-surface geomorphological processes. Grouting of the annulus of the tunnel will also aid pipeline stability.

Survey work to date has identified the presence of large potential rotational failure planes in the coastal hill under which microtunnelling is planned (Ref. 19.6). Almost all of the coastal hills within the region are subject to active seismogenic landslides. It is possible that the potential failure planes located within the hill structure may be associated with this type of tectonic activity. The microtunnel alignment is below the main areas of identified instability in the near-surface rock mass (Ref. 19.6) and is considered to be beneath the zone of influence for the majority of potential near-surface slope failures. If movement along the potential deep-seated rotational failure planes is activated, this might influence microtunnel stability (Ref. 19.17); in the event of a major landslide the integrity of the Pipeline may be affected.

The rate of coastal erosion, not including landsliding, is not considered a geohazard to the Project because of the decision to microtunnel (Ref. 19.6).

The inactive Shingarsky Fault is crossed by the microtunnels. Additionally, fissure zones, intersecting the Pipeline route, have been locally identified in the coastal ridge; the fissure zones may have formed through local tectonic or gravity-induced ground movements. If these fault and fissure zones are associated with significant groundwater flows, this may lead to difficult microtunnelling conditions. The potential impacts of more permeability zones will be mitigated through tunnel boring machine (TBM) monitoring and slurry management (**Chapter 5 Project Description**).

As described in **Chapter 5 Project Description**, the design of the landfall facilities takes into account the local topography and geomorphology. The preparation of the site for the construction of the landfall facilities will require earthworks in order to prepare a level area. The levelled platform area will have both upward and downward slopes. Engineered slopes are required to stabilise the platform and ensure that the landfall facilities will not be at risk from landslides from the surrounding hill slopes during its operational life.

Active geomorphological processes associated with fluvial erosion occur in the valleys. Flooding is more prevalent in spring, associated with rain events and snow melt and flash flooding may occur at the Shingar River crossing and at the Graphova Gap. This may cause gully erosion, liquefaction of sediments or slope instability.

Only one watercourse is crossed by the open-cut pipelines, an unnamed tributary of the Sukko River in the Graphova Gap. This unnamed tributary has no or low flow during the summer months and more significant flow during the winter months. The design of the Pipeline crossing at the Graphova Gap takes into account the local topography and geomorphology (**Chapter 5 Project Description**). After installation of the Pipeline in the trench, protective measures will be installed to prevent possible flash floods from eroding the bed of the watercourse and exposing the external coating of the Pipeline (**Chapter 5 Project Description**). Due to the watercourse being located within a relatively steep sided gully, grading and earthworks will be required to ensure stability of the slopes during the operational phase of the Project. Therefore, there will be some degree of change to the original profiled of the gully. Geotechnical stabilisation of the slopes is incorporated into the design profile of the crossing. Rehabilitation of the slopes, including reseeding, as described in **Chapter 11 Terrestrial Ecology**, will help mitigate against erosion by surface run-off. As described in **Chapter 5 Project Description** and **Chapter 8 Soils, Groundwater and Surface Water**, mitigation measures will be required during construction and operation to reduce the risk of impacts associated with flooding at this crossing.

Marine Geohazards

Geohazards associated with the Marine Study Area (landfall section and nearshore section) include seismic activity, tsunamis and coastal erosion. Geohazards associated with the Marine Study Area (offshore section) include seismic activity, steep slopes, slope stability issues and mass movements, rock outcrops and boulders, soft sediments, gas seeps and gas hydrates.

Historical slope failures of the coastal hill along the Anapa coastline are evident in the coastal topography. There is evidence for the distal part of at least one of these failures travelling across the continental shelf as a debris flow.

Coastal processes can also create geohazards. Coastal erosion and pipeline scour may occur due to metocean processes. Wave induced liquefaction of sandy deposits near the shore may occur. The decision to microtunnel (**Chapter 4 Analysis of Alternatives**) helps mitigate the risks associated with coastal geohazards.

Earthquakes in the Black Sea region may also create tsunamis. Seismic events localised on the Russian continental slope are often associated with tsunamis (for example earthquakes in 1905 and 1966). Tsunami in the area, however, are not always related to seismic events, but may also be caused by underwater slope failures. Tsunami run-up may cause pipeline scour and inundation or erosion of pipeline in shallow water.

As described in **Chapter 5 Project Description**, shallow water sections of the subsea pipelines (for water depths less than approximately 88 m, including buried pipelines) will be additionally coated with reinforced concrete to increase their weight to improve stability against sea currents and provide additional protection from external damage.

As described in **Chapter 4 Analysis of Alternatives**, the Pipeline route alignment on the continental shelf was based primarily on environmental considerations.

The Russian Shelf Break is very distinct and is characterised by a very steep slope which shows numerous signs of instability (Ref. 19.9). Bedrock outcrops and very thin sediment drape over coarse-grained material along valleys suggests that downslope material transport by erosion is continuing at present (Ref. 19.6). Sandy deposits near the shelf break may be susceptible to liquefaction.

The continental slope morphology offshore from Anapa is characterized by a highly dissected, dendritic canyon system and by numerous topographic constraints. The continental slope has numerous mass wasting features including submarine landslides (including tension cracking associated with potential failures at the shelf break), slump deposits, debris flows, and turbidity currents (Ref. 19.6). The Anapa Canyon is one of the key features of the continental slope. The Anapa Canyon formed during the Holocene (more than 5,000 years ago) but is currently not actively growing (Ref. 19.8). Currents and flows along the slope seem to be channelised along valleys and the canyon thalweg (Ref. 19.6). Rotational slide features have been identified in the subsurface through seismic profiling.

As described in **Chapter 4 Analysis of Alternatives**, the Pipeline route alignment was based on consideration of engineering and environmental constraints. The choice of a suitable slope crossing for the continental slope was critical. Geohazard mapping was undertaken to facilitate route alignment based on the marine survey findings and associated engineering assessments (Ref. 19.7 and 19.8). The route selected takes into account rugged morphology and sediment stability. Two stable submerged gullies on the side of Anapa Canyon were selected for pipeline routing. Although the pipeline routes skirt around the main Anapa Canyon, turbidity currents associated with this feature may cause localised scour. In addition, the occurrence of mass movements triggered by events such as earthquakes must be taken into account (Ref. 19.6).

The presence of very low strength clay and silt as is found on the abyssal plain may cause pipeline burial. Very low strength sediments may also cause bearing capacity failure leading to pipeline tension. This has been taken into account in the design of the Pipeline (**Chapter 5 Project Description**).

Submarine rock falls occur on the upper slope (Ref. 19.7). This may dent or crush the Pipeline. Pinnacle rock outcrop and boulders on the continental slope may create free spanning issues as well as point loading which may compromise the pipeline coating integrity. As described in **Chapter 5 Project Description**, in the Project Area (offshore section), the Pipeline will be generally laid directly on the seabed to minimise seabed disturbance. However, although the route of the pipelines have been designed to minimise seabed intervention requirements, some intervention will be required in specific areas, either before or after pipe-laying. This is to limit or remove pipeline free span lengths (for example in areas where the sea bed is rough and uneven) and to protect the Pipeline from geo-hazards such as rockfall in areas of excessive slopes (for example on the continental slope). Support structures will be strategically placed to provide vertical support to the Pipeline at excessive span length locations.

Seismic activity in the region may initiate slumping and turbidity flows. Seismically induced liquefaction of sandy deposits at the shelf break may occur.

Active faults were not observed on any of the sub-bottom profiles conducted along the Pipeline routes. Surface rupture from an active fault is not considered to be a significant geohazard along the Pipeline route in the Marine Project Area (Ref. 19.8).

The presence of shallow gas in either free form or as a hydrate may act as a potential trigger for upper continental slope slumping and associated debris flows. Potential freespan issues may arise above gas escape structures such as pockmarks or plumes. Conversely, doming due to gas build-up may occur prior to gas release causing pipeline stress if the Pipeline were located over the feature. No existing dome features have been identified along the Pipeline route (Ref. 19.9). Carbonate mounds that indicate the presence of gas seeps have been locally observed within the Marine Study Area (Ref. 19.9). Other potential impacts associated with gas include the lowering of bearing potential, the release of toxic gases, explosions or loss of vessel buoyancy. Gas hydrates are a hazard owing to the potential for phase changes from solid to fluid.

Soil creep is associated with the deeper soft sediments on the continental slope. Earthquakes of ≥4.7 moment magnitude (Mw) are likely to cause the development of small mud slides in the area of the continental slope toe, especially in areas where the slope exceeds 7 to 10º. A potential liquefaction hazard has been identified where sandy deposits are present on the continental slope. The specification for the Pipeline design has taken into account the geotechnical properties of the seabed.

There were no significant engineering constraints on the choice of route across the Russian abyssal plain (**Chapter 4 Analysis of Alternatives**).

Glossary

Term	Explanation
Construction and Pre-Commissioning Phase	Phase of the Project (2013-2018) which involves all construction activities and includes an operational ramp-up period from late 2015 to late 2018.
Decommissioning	Shutdown and dismantling of any facilities, including reinstatement of site.
Emergency Preparedness and Response Plan	The Emergency Preparedness and Response Plan defines how South Stream Transport plans, prepares and manages incidents and emergencies.
Emergency Response Plan	Emergency Response Plans are required for each high risk emergency incident / scenario as identified by the Emergency Risk Analysis. Contractors who will be doing the work will be responsible for preparing Emergency Response Plans for their work activities, and specifically those events identified by the Emergency Threat Analysis.
Emergency Shutdown Valve (ESV)	An actuated valve designed to stop the flow of hazardous fluids or hydrocarbon gases upon the detection of a dangerous event. This provides protection against possible harm to people, equipment or the environment.
Emergency Threat Analysis	Emergency Threat Analysis determines the risks posed by potential emergencies and the need for specific Emergency Response Plans and related procedures as a contingency for emergency events.
Environmental and Social Impact Assessment	Refers to both the process of assessing environmental, social-economic and cultural heritage impacts and to the report documenting the process and its' outcomes. Developed in accordance with international finance standards and guidelines such as the IFC Performance Standards.
Good International Industry Practice	Good International Industry Practice is the exercise of professional skill, diligence, prudence and foresight that would reasonably be expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally.
Landfall facilities	Facilities that are part of the Russian or Bulgarian landfalls of the Project and whose goods or services are essential for the successful operation of the Project including metering stations, PIG traps(launchers or receivers) and ESDVs.
Mitigation	Specific measures developed through the ESIA process to prevent, avoid and reduce adverse impacts to a level considered to be socially acceptable. Can also include measures to enhance beneficial impacts.

Nearshore Section	Four buried pipelines extending from the exit point of the microtunnels, located approximately 400 m from the coast at a water depth of approximately 23 m to a maximum water depth of 30 m.
Offshore Section	Four pipelines each approximately 225 km in length laid directly on the sea bed from the maximum water depth where dredging works will take place (30-35 m) to the boundary between the Russian and Turkish EEZs.
Oil Spill Prevention and Response Plan	All contractors and operators of vessels working on behalf of South Stream Transport will be required to developing and implementing an Oil Spill Prevention and Response Plan which will define actions to be taken to minimise the risks of marine oil spillages, as well as the actions to be undertaken following a spillage.
Spill Prevention and Response Plan	Plan which will be developed and maintained by each Project contractor defining the measures to be taken to minimise the risk of onshore oil spillages and the responses to be taken in the event of a spillage.
South Stream Offshore Pipeline	The overall South Stream Offshore Pipeline covering all three countries (Russia, Turkey and Bulgaria).
South Stream Transport	Previously, the Project was developed by Gazprom during 2009-2011, and then by South Stream Transport AG during 2011-2012. South Stream Transport then moved head office from Switzerland to the Netherlands and established South Stream Transport BV in November 2012.
The Project	South Stream Offshore Pipeline – Russian Sector.

Abbreviations

Term	Explanation
ALARP	As Low As Reasonably Practicable
CCR	Central Control Room
CCTV	Closed-Circuit Television
CTMP	Construction Traffic Management Plan
DNV	Det Norske Veritas
EEZ	Exclusive Economic Zone
EHS	Environmental, Health and Safety
E&I	Electrical and instrumentation
EMSA	European Maritime Safety Agency
EPC	Engineering, Procurement and Construction
ESD	Emergency Shutdown
ESIA	Environmental and Social Impact Assessment
ESMP	Environmental and Social Management Plan
ESV	Emergency Shutdown Valves
EU	European Union
GIIP	Good International Industry Practice
GR	Group Risk
HFO	Heavy Fuel Oil
HSSE-IMS	Health, Safety, Security and Environment Integrated Management System
IFC	International Finance Corporation
IFO	Intermediate Fuel Oils
IR	Individual Risk

MDO	Marine Diesel Oil
MGO	Marine Gas Oil
MPL	Maximum Permitted Level
OGP	International Association of Oil and Gas Producers
OHS	Occupational Health and Safety
OSCAR	Oil Spill Contingency and Response
PAH	Polycyclic Aromatic Hydrocarbons
PSDC	Project Specific Design Code
ppb	Parts per billion
QRA	Quantitative Risk Assessment
SMPEP	Shipboard Marine Pollution Emergency Plans
SOPEP	Shipboard Oil Pollution Emergency Plans
UK	United Kingdom

References

Number	Reference
Ref. 19.1	Quantitative Risk Assessment - Onshore Sections. Intecsea Report 10-00050-10-SR-REP-0040-0010 dated October 2013.
Ref. 19.2	Black Sea Diesel and Fuel Release Modelling: South Stream Development. Genesis: Technical Note August 2013.
Ref. 19.3	International Association of Oil and Gas Producers (OGP) Risk Assessment Data Directory Report No. 434-10. 10 March 2010.
Ref. 19.4	European Maritime Safety Agency (EMSA) Review 2010. Accessed on 12 September 2013. Available at: http://www.emsa.europa.eu/news-a-press-centre/external-news/item/1219-maritime-accident-review-2010.html.
Ref. 19.5	International Association of Oil and Gas Producers (OGP) Risk Assessment Data Directory Report No. 434-16. 16 March 2010.
Ref. 19.6	Intecsea Worley Parsons Group (2013) South Stream Offshore Pipeline FEED Pipeline Geohazard Summary Report 10-00050-10-SS-REP-0050-0003, 19-April-13, Rev B1.
Ref. 19.7	Intecsea Worley Parsons Group (2013), South Stream Offshore Pipeline FEED Pipeline Geohazard Impact Assessment Report 10-00050-10-MX-REP-0060-0013, 19-April-13, Rev 0.
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Ref. 19.9	Seascape Consultants Ltd, 2013. The Recent History of the Black Sea including Interpretation of Newly Acquired Seabed Survey Data for the South Stream Offshore Pipeline Project. Report to South Stream Transport BV. Ref. 2013/08.