Chapter 12 Hazard Analysis and Risk Assessment (Unplanned Events)
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12 HAZARD ANALYSIS AND RISK ASSESSMENT

12.1 Introduction

This chapter updates the hazard analysis and risk assessment studies carried out for the proposed SCPX Project concept (as described in the SCPX Final ESIA). This chapter focuses on updates to unplanned events associated with the change in diameter from 56” to 48” and the proposed additional sections of pipeline.

It describes and assesses unplanned events that could potentially cause risks to public safety and harm to the environment. It also outlines the proposed mitigation measures and the strategy proposed that aims to manage the risks potentially associated with the Project.

A full description of the principles of hazard and risk management and the risk assessment process can be found within Chapter 12 of the SCPX Final ESIA.

12.2 Pipeline Design and Risk

In Azerbaijan, the SCPX pipeline, including the proposed additional sections of pipeline, generally follow those of the existing BTC and SCP pipelines, avoiding existing development and local infrastructure as far as practicable. However, a number of communities are relatively close to the pipeline ROW.

The proposed SCPX design has located the SCPX route and block valve stations (BVR) where they can share utilities with existing BTC and SCP BVRs, while allowing sufficient distance between the proposed SCPX BVRs and the BTC and SCP BVRs, and sufficient separation from the existing BTC and SCP pipelines to minimise the likelihood of escalation in an accidental event (see Section 12.2.3 and Section 12.2.5).

12.2.1 Pipeline Design Codes and Standards

Table 12-1 presents design data for the 48”-diameter SCPX pipe.

<table>
<thead>
<tr>
<th>Data</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line pipe data</td>
<td>SCPX outer diameter</td>
<td>48”/1219mm</td>
</tr>
<tr>
<td></td>
<td>Specified minimum yield strength</td>
<td>485MPa</td>
</tr>
<tr>
<td></td>
<td>Manufacturing tolerance</td>
<td>Nominal wall thickness +/-0.75mm</td>
</tr>
<tr>
<td>Operational data</td>
<td>Design life</td>
<td>30 years</td>
</tr>
<tr>
<td></td>
<td>Design pressure</td>
<td>95.5 barg</td>
</tr>
<tr>
<td></td>
<td>Maximum design temperature</td>
<td>74°C</td>
</tr>
<tr>
<td></td>
<td>Minimum design temperature</td>
<td>-10°C</td>
</tr>
<tr>
<td>Coating data</td>
<td>External three-layer polyethylene thickness</td>
<td>3.2mm</td>
</tr>
<tr>
<td></td>
<td>External three-layer polyethylene density</td>
<td>900kg/m³</td>
</tr>
<tr>
<td></td>
<td>Factory-applied concrete-coating density</td>
<td>3500kg/m³</td>
</tr>
<tr>
<td></td>
<td>Applied for specific hazards at river crossings etc., for anti-buoyancy reasons or local protection</td>
<td>3500kg/m³</td>
</tr>
<tr>
<td></td>
<td>Field-applied concrete-coating density</td>
<td>2400kg/m³</td>
</tr>
</tbody>
</table>
A combination of a three-layer polyethylene coating, field joint coating and an impressed cathodic protection system aim to protect the pipeline from the risk of external corrosion. It is weight coated with concrete where negative buoyancy is needed in wet areas.

The 48”-diameter SCPX pipe is being designed in accordance with the latest version of the long-established American Society of Mechanical Engineers (ASME) B31.8 code for ‘Gas Transportation and Distribution Piping Systems’. Other international standards, as applicable, including applicable American Petroleum Institute (API) standards, have also been incorporated into the design.

ASME B31.8 approach to public safety is based on design factors specifying the use of different classes of pipe depending on land use and population density (see Table 12-2). It implicitly mitigates the key risk associated with gas pipelines by specifying design factors that are intended to reduce the likelihood of pipeline ruptures in populated areas. The design factor is the ratio between the actual operating stress of the pipeline and the yield stress of the material from which it is made, and is an indicator of how much stress the pipeline could endure before it starts to deform. Increasing the pipeline wall thickness gives a greater margin between operating stress and yield stress and is considered to provide increased protection against mechanical impacts (e.g. from excavating and agricultural machinery), which are historically a major cause of major pipeline failures. For most of its length, the SCPX pipeline has a design factor of 0.72 (Location Class 1, Division 2).

Table 12-2: Summary of ASME B31.8 Land Use/Location Class Criteria for Design Factor

<table>
<thead>
<tr>
<th>Design Location Class</th>
<th>Typical Land Use for Location Class</th>
<th>No. of Buildings for Human Occupancy Within 200m of Pipeline</th>
<th>Design Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Division 1)</td>
<td>Sparsely populated areas, wasteland, desert, mountain, grazing and farmland</td>
<td>&lt; 10</td>
<td>Greater than 0.72 but equal to or less than 0.8</td>
</tr>
<tr>
<td>1 (Division 2)</td>
<td>Sparsely populated areas, wasteland, desert, mountain, grazing and farm land</td>
<td>&lt; 10</td>
<td>≤ 0.72</td>
</tr>
<tr>
<td>2</td>
<td>Fringe areas around cities and towns, industrial areas, ranch or country estates</td>
<td>Greater than 10 and less than 46</td>
<td>0.6</td>
</tr>
<tr>
<td>3</td>
<td>Suburban housing developments, shopping centres, residential areas, industrial areas and other populated areas not meeting Location Class 4 requirements</td>
<td>Greater than 46</td>
<td>0.5</td>
</tr>
<tr>
<td>4</td>
<td>Includes areas where multi-storey buildings (4 or more floors) are prevalent, where traffic is heavy or dense and where there may be numerous other underground utilities</td>
<td>Any number</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Note 1: In multi-storey units, each dwelling within the unit is considered as an independent dwelling.
Note 2: Pipelines in Location Class 1 or 2 passing near places of public assembly or concentrations such as schools, hospitals or recreational areas of an organised nature, including outside areas that are frequently used shall meet the requirements of Location Class 3.

To comply with Section 840.2.2 of ASME B31.8, mechanical design calculations used the design factors shown in Table 12-3 to determine the applicable pipe wall thickness in areas where there are many existing dwellings, or where future development of communities and population growth are anticipated. This table includes the revised wall thicknesses that apply to the 48” pipeline.
The number of properties close to the 48”-diameter proposed SCPX route in Azerbaijan varies in different parts of the ROW. To identify the design factor and wall thickness to be used along the proposed SCPX route in Azerbaijan, the Project carried out a desktop study and field verification exercise to determine the building density within a 200m zone and 500m zone either side of the route. The results of the building density study for the additional section of pipeline resulted in the selection of the location classes shown in Table 12-4. Location classes for the pipeline loop from SCPX KP34 to KP423 are unaffected by the reduction in diameter and are described in the SCPX Final ESIA (Table 12-4).

Table 12-4: ASME31.8 Location Classes on the Proposed Additional Section of SCPX Route in Azerbaijan

<table>
<thead>
<tr>
<th>Location Class</th>
<th>Comments on Building Proximity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>&gt; 10 buildings within 200m of the pipeline</td>
</tr>
<tr>
<td>Class 2</td>
<td>&lt; 10 buildings within 200m of the pipeline</td>
</tr>
</tbody>
</table>

As can be seen from Table 12-4, the route of the proposed additional section of pipeline has avoided populated or sensitive areas. Details of design specifications relating to road and river crossings can be found in the SCPX Final ESIA.

In addition an increased wall thickness with a design factor of 0.6 will be applied where the pipeline passes seismic faults to meet the requirements of API RP 1102 (D5-034).

Analysis has been performed that demonstrates that within 48”-diameter class 2 and class 3 pipeline there is a lower likelihood of failure by a full bore rupture (FBR). The risk of FBR is considered as low as reasonably practicable in risk assessment terms.

12.2.2 Safety Risk Results and Discussion

Consequence modelling techniques (the Process Hazard Analysis Software Tool, PHAST) and the BP Cirrus software programme) were used to predict the distance to heat radiation contours of the ignition of gas released from a 75mm-diameter hole and alternatively a full bore rupture in the buried 48”-diameter SCPX pipeline. The 75mm hole is considered representative of a “leak-before-rupture scenario” as a result of a large corrosion related hole in the pipeline.

Table 12-5 presents the distance to thermal radiation contours of 6.3kW/m², 12.5kW/m² and 35kW/m² from an ignited gas jet fire resulting from a FBR and a 75mm-diameter leak.

Table 12-5: Thermal Radiation Contours for Buried High-Pressure Pipelines

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Leak Size (mm)</th>
<th>Flame Length (m)</th>
<th>Radiation Contours (either side of pipeline, m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>35kW/m²</td>
</tr>
<tr>
<td>48” SCPX pipe</td>
<td>FBR</td>
<td>385</td>
<td>200</td>
</tr>
<tr>
<td>75 mm</td>
<td>73</td>
<td>43</td>
<td>90</td>
</tr>
</tbody>
</table>
The proposed additional section of pipeline is generally designed in accordance with a Location Class 1, Division 2 pipeline (the same as the existing SCP) and will have a design factor of 0.72 and a nominal wall thickness of 16.7mm.

However, throughout the entire SCPX route within Azerbaijan significant lengths of the pipeline have been assigned a Location Class of 2 or 3, resulting in increased wall thickness for these sections as shown in Table 12-4 of the SCPX Final ESIA (reduced design factor results in an increased wall thickness.). With this increased wall thickness the pipeline is considered far less likely to rupture. A 75mm-diameter leak hole would be expected to occur as a worst-case scenario, and as indicated in Table 12-5 the radiation contour would reach a distance of approximately 130m from the pipeline, before it reduced to a level at which personnel could reasonably escape (6.3kW/m2).

The change in diameter of the pipeline and the proposed additional section of pipeline do not change the overall risk levels assessed in the SCPX Final ESIA. Considering the BTC, SCP, WREP and SCPX pipelines together slightly increases the overall risk levels, but even with the introduction of SCPX pipeline the risk levels are considered to remain extremely low. As long as adequate pipeline separation is implemented, an accidental event is considered unlikely to escalate to an adjacent pipeline in the ROW.

### 12.2.3 Separation Distances

#### 12.2.3.1 Pipeline

When routed on the right hand side of the ROW corridor, the proposed 48”-diameter SCPX route is adjacent to the SCP gas pipe; when routed on the left hand side, it is adjacent to the BTC oil pipeline.

Modelling studies comparing the results from two Pipeline Research Council International (PRCI) models, a BP model and industry data from incidents on similar pipeline were used to determine the minimum recommended distance between the SCPX pipe and one of the existing pipelines. The models simulated a full-bore rupture across the entire diameter of the SCPX pipe operating at 90 barg (the worst-case event and one which is considered unlikely in class 2 and class 3 pipelines owing to the design mitigations discussed in Section 12.2.1). The modelling provided an estimate as to whether the crater from an explosion would expose the adjacent pipeline, thereby potentially causing a loss of integrity, and whether heat radiation would be likely to affect the adjacent exposed pipeline.

The largest crater radius from the modelling results was 15.2m produced by the BP model, which presents a worst-case scenario (i.e. a larger crater radius than the PRCI models and actual historical data). A general minimum separation distance of 20m is applied between SCPX and SCP/BTC. At crossings, additional control of work measures will be applied (D11-04). When SCPX is adjacent to BTC to allow room for setting out and constructing the 48” pipeline, the actual separation distance will generally be in the region of 36m (see Figure 12-3 of the SCPX Final ESIA).

It should be noted, that the crater size resulting from a pipeline explosion is a function of the pressure (and not the flow rate) and thus the risk associated with the SCP sections of the pipeline does not change as the operating pressure remains at or below 90 barg pressure.

There are currently expected to be in the region of 12 points in Azerbaijan where the proposed additional section of SCPX route crosses under some or all of the existing BTC, SCP and WREP pipelines. Where the SCPX pipeline crosses buried services or pipelines, trenchless or open cut crossing methods will be adopted. Design mitigation measures that will be applied at crossings remain as described in Section 12.2.3 of the SCPX Final ESIA.
12.2.3.2 **Block valves**

Block valves (BVRs) allow sections of pipelines to be isolated from the rest of the pipeline to carry out maintenance or in response to an emergency. The distance between one BVR and the next on the SCP pipeline was determined using a risk-based approach consistent with the ASME B31.8 standard (2007) that considered:

- The amount of gas expected to be released for maintenance blowdowns, leaks or ruptures
- The time expected to be needed to blowdown an isolated section of the pipeline
- The potential impact in the area of the gas release.

As the maximum allowable operating pressure of the SCPX system (90 barg) will be the same as for the SCP system, the risk assessment concluded that the maximum distance between the proposed SCPX BVRs could be the same as that for the SCP BVRs, which are spaced, on average, 77km apart. It was also decided that the proposed SCPX BVRs would be most appropriately located close to the existing BTC and SCP BVRs so that they could share utilities and to reduce the small cumulative environmental impact associated with the additional land needed for the new BVRs. Therefore, in Azerbaijan, there are likely to be stand-alone block valves, close to the existing SCP and BTC block valves, at KP78, KP152, KP227, KP298 and KP386 (SCP kilometres).

The risk analysis undertaken to evaluate the potential for a major accident at an SCPX block valve affecting a block valve on the SCP or BTC pipelines and to determine the appropriate separation distance of the pipelines at block valve stations was updated to consider the proposed additional sections of pipeline and difference in pipeline diameter. The result of the analysis are discussed in the SCPX Final ESIA and were unaffected by the proposed changes. The results suggest at the block valve sites the separation distance between the 48” SCPX pipeline and the 42” SCP pipeline and the SCPX block valves and the BTC/SCP block valves will be no less than 28m (D11-05). However, to further improve separation between the block valves the local SCPX spacing is increased to 40m between the pipelines.

### 12.2.4 Pipeline Protection Zones

The zones in which construction activities are prohibited or restricted and the zones in which developers must consult with the operators of pipeline prior to construction activities are unaffected by the proposed additional sections of pipeline and change in pipeline diameter and are presented in the SCPX Final ESIA. These zones apply to the additional sections of pipeline.

### 12.2.5 Fault Crossing Mitigations

The proposed pipeline follows the SCP/BTC pipeline corridor, which was designed to take account of geological fault lines in Azerbaijan. The SCPX Project reviewed the active fault crossings for the existing SCP pipeline to confirm the results of the fault identification process, and the methodology for determining the potential rupture zones and characterisation of the faults.

Following Project design updates, the proposed SCPX route now starts at SCP KP23 (SCPX KP0) and crosses the following faults:

- A fault zone (mud volcano fault) – SCPX KP1.1
- Two faults at Hajigabul at SCP KP26.9 and KP27.9.

The section of the pipeline trench that crosses the faults will be excavated in a trapezoidal shape, lined with geotextile membrane and filled with non-cohesive, graded aggregate (D5-006). This will allow free and unrestricted movement of the pipe with the ground surface during a potential seismic event and avoid causing a rupture.
12.3 Impact Significance Assessment

12.3.1 Potential Impacts of Unplanned Events: Construction
The proposed additional sections of pipeline do not change the impacts of unplanned events during construction which are described in Chapter 12 of the SCPX Final ESIA.

12.3.2 Potential Impacts of Unplanned Events: Pipeline Operation

Pipeline failure
In historic cases when pipeline integrity has failed and leaking gas has found a source of ignition and exploded, the following potential outcomes may occur:

- Crater formation close to the source of the leak
- A fireball
- An area of earth scorching around the crater
- A wider area in which vegetation, trees, crops and buildings could potentially be damaged by fire
- An even wider area in which noise from the explosion could potentially cause damage or disturbance to residents
- Release of greenhouse gases.

In the very unlikely event of a full bore rupture of the 48"-diameter pipeline, the above outcomes may potentially be less significant than those associated with a 56"-diameter pipeline owing to the smaller diameter of the release point. Following a review of the risk assessment for the 48"-diameter pipeline it is felt that a decrease in pipeline diameter does not significantly affect the overall impacts, and as the event probability remains unchanged for the 48"-diameter pipeline then the overall level of risk is therefore unaffected by the reduction in pipeline diameter. These outcomes were discussed in the SCPX Final ESIA.

There is a slight reduction in the volume of greenhouse gas that could potentially be released in the event of an incident. Generally, the maximum distance between block valves on the SCPX pipeline in Azerbaijan will be approximately 77km, therefore, in the unlikely event of a full bore rupture, the largest gas release would be approximately 77000 tonnes of pipeline gas or 200,000 tonnes of CO₂eq. If the released gas ignites, emissions would be approximately 25,000 tonnes of CO₂. Again, this reduction has not affected the assessment of potential impact significance.

River crossing exposure
The impact of a buried pipeline being exposed at a river crossing is unchanged by the proposed additional sections of pipeline or change in pipeline diameter and is discussed in the SCPX Final ESIA.

12.4 Risk Assessment
Table 12-6 provides an assessment of the potential risks associated with unplanned events. The proposed additional sections of pipeline or change in pipeline diameter have not changed the assessment presented in the SCPX Final ESIA.
Table 12-6: Impact and Probability Assessment for Unplanned Events

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Event: Gas release from pipeline with explosion</td>
<td>A30 Community safety Exposure to thermal radiation</td>
<td>Very high</td>
<td></td>
<td>D11-02, D11-03, D11-04, D11-05, D12-02, D12-03, D5-001, D5-006, D-5010, D6-011, D6-034, 4-14, 36-02, OP20, OP121, OP123, OP124, OP125, OP128, OP129, OP130, OP131, OP132, OP133, OP136, OP140, OP143, X5-17, 32-07</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>A4 Loss of soil structure Crater formation</td>
<td>C3 Medium</td>
<td></td>
<td></td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>A8 Visual intrusion Visible fireball</td>
<td>B2 Low</td>
<td></td>
<td></td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>A3 Soil erosion Ground cover removed where earth is scorched</td>
<td>B3 Low to Medium</td>
<td></td>
<td></td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>A17 Loss of habitat Fire damage to vegetation</td>
<td>A2 Low</td>
<td></td>
<td></td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>A32 Loss of agricultural land Damage to crops</td>
<td>B3 Low</td>
<td></td>
<td></td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>A35 Damage to third party infrastructure Damage to buildings</td>
<td>B2 Low</td>
<td></td>
<td></td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>A25 Noise Noise disturbance from major incident</td>
<td>C5 High</td>
<td></td>
<td></td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>A31 Community health Anxiety caused to residents in surrounding communities</td>
<td>Low</td>
<td></td>
<td></td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>A23 Release of gases to atmosphere Greenhouse gas emission</td>
<td>C4 Medium</td>
<td></td>
<td></td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

12.5 Mitigation Measures

The mitigation measures for unplanned events have remained unchanged and are generally:

- Design measures that limit both the impacts of the unplanned event and the probability that it may occur
- Operational monitoring activities that make an unplanned event less likely to happen, but do not affect the impacts if it does happen, or
- Emergency response activities that limit the area impacted or the time for which the impact lasts and which prioritise crisis management and emergency response in the following order:

1. People: Employees, contractors, suppliers, customers and communities
2. Environment: Air, water, land, spillages and areas of sensitivity
3. Property: BP, JV, contractors, communities and third-party facilities
4. Business: Supply, production and reputation

These mitigations are discussed fully in Section 12.5 of the SCPX Final ESIA and only additional or amended mitigations are described below.
12.5.1 *Mitigation Measures Incorporated into the Design*

The same range of measures that have been incorporated into the design of the SCPX pipeline as a whole have been incorporated into the SCPX Project design updates to reduce the likelihood of an unplanned event. Please refer to Section 12.5.1 of the SCPX Final ESIA for details.

12.6 *Residual Risk*

The overall assessment of residual risk is unaffected by the change in diameter from 56" to 48" and the additional pipeline section and is generally of low significance with a medium significance for the risks to community health and safety from unplanned events on the pipeline.

A full discussion on residual risks can be found in Chapter 12 of the SCPX Final ESIA.