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SAFETY KNOWS NO BORDERS: SUBMARINE GAS PIPELINE FROM PRC TO BPPS

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1. INTRODUCTION

Castle Peak Power Company Limited (CAPCO), a joint venture between CLP Power Hong Kong Limited (CLP) and ExxonMobil Energy Limited (EMEL), is pursuing a new supply of natural gas to replace it's current fuel supply from the depleting Yacheng 13-1 field. Natural gas is widely recognised as a comparatively clean burning fuel. A reliable fuel supply to Black Point Power Station (BPPS) is crucial in facilitating CAPCO's ability to comply with Government's air emission standards.

On 28 August 2008, the Hong Kong Special Administrative Region (HKSAR) Government signed a Memorandum of Understanding (MoU) with the National Energy Administration of the Central People's Government (NEA) in support of a continuous supply of natural gas to Hong Kong [1]. The MoU enables CAPCO to work with gas suppliers in the Mainland to obtain natural gas for BPPS. In the implementation of the MoU, CAPCO will establish a joint–venture with PetroChina Company Limited (PetroChina) to develop a submarine gas pipeline linking DaChan Island, Shenzhen to BPPS for replacement gas supply from Mainland China to Hong Kong. This new pipeline will enable a natural gas supply source to Hong Kong via the Second West-East Natural Gas Pipeline. PetroChina will design, construct and operate the new pipeline on behalf of the joint-venture while CLP Power, as CAPCO's operator will design, construct and operate CAPCO's new down stream gas receiving station (GRS) at BPPS.

In recent years, there has been an increasing number of examples involving cooperation on infrastructure, utilities and development projects between HKSAR and Mainland China, in particular the Guangdong Province. Due to the geographic proximity of the HKSAR and Guangdong in the Mainland, cross-boundary projects involving these two areas are likely to share similar risk exposures and design challenges. This would require close liaison and collaboration on both sides to ensure the design, construction and operation are implemented in a safe and professional manner. In this regard, safety management of cross-boundary projects has become an increasingly important issue for regulators and stakeholders.

[1] HKSAR (2008) Memorandum of Understanding on Energy Co-operation. Press Release. Accessed on <http://www.info.gov.hk/gia/general/200808/28/P200808280188.htm>

2. PETROCHINA'S SECOND WEST TO EAST PIPELINE PROJECT

PetroChina is one of the largest energy companies in the world with businesses covering all aspects of oil and gas projects for upstream and downstream operations. Their natural gas pipeline sector is the largest in China and delivers approximately 75% of China's total requirements.

As a part of the National Energy Plan, the People's Republic of China (PRC) has established a natural gas pipeline system for delivery from the western provinces to the more populated east-central China and the Yangtze River Delta. The first of these projects was the West-East Gas Transmission Project I gas pipeline, was completed in 2004, providing ~ 17 billion cubic meters of gas per year. The completion and operation of the project signifies the initial establishment of PetroChina's trunk line network in China.

In February 2008, the NEA approved the second West-East Gas Transmission Pipeline Project and is China's first major energy project to transfer natural gas resources from outside its borders. The project stretches from Khorgos Port in Xinjiang in the west, to Guangzhou and Shenzhen in the south, and to Shanghai in the east, passing through 14 provinces, regions and cities. The main trunkline and eight branches have a combined length of about 8,600 kilometers (Figures 1 and 2).

The second West-East Pipeline is separated into west and east segments at Zhong Wei. The west segment comprises Khorgos-Zhong Wei trunkline and Jingbian Branch while Zhong Wei-Guangzhou pipeline forms the east segment. Construction of the west segment of the pipeline was started in February 2008 and is now in operation. Construction of the east segment commenced in February 2009 and the Zhong Wei-Huangpi trunkline was commissioned in November 2010. The entire project is expected to be operational in 2012. Capacity of the pipeline system is ~ 30 Bcm/yr with a maximum trunkline design pressure of 120 bar.

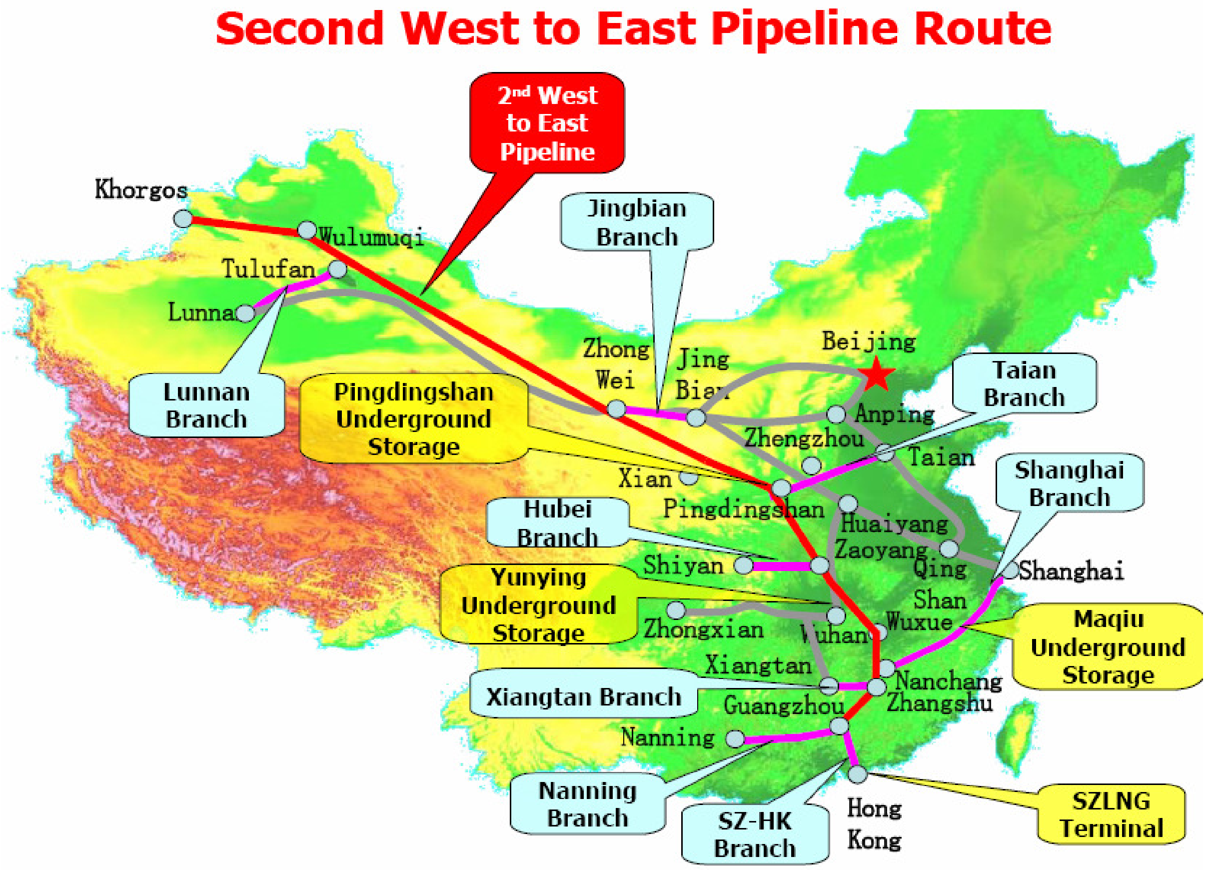

Figure 1 Second West to East Pipeline Route in Mainland China

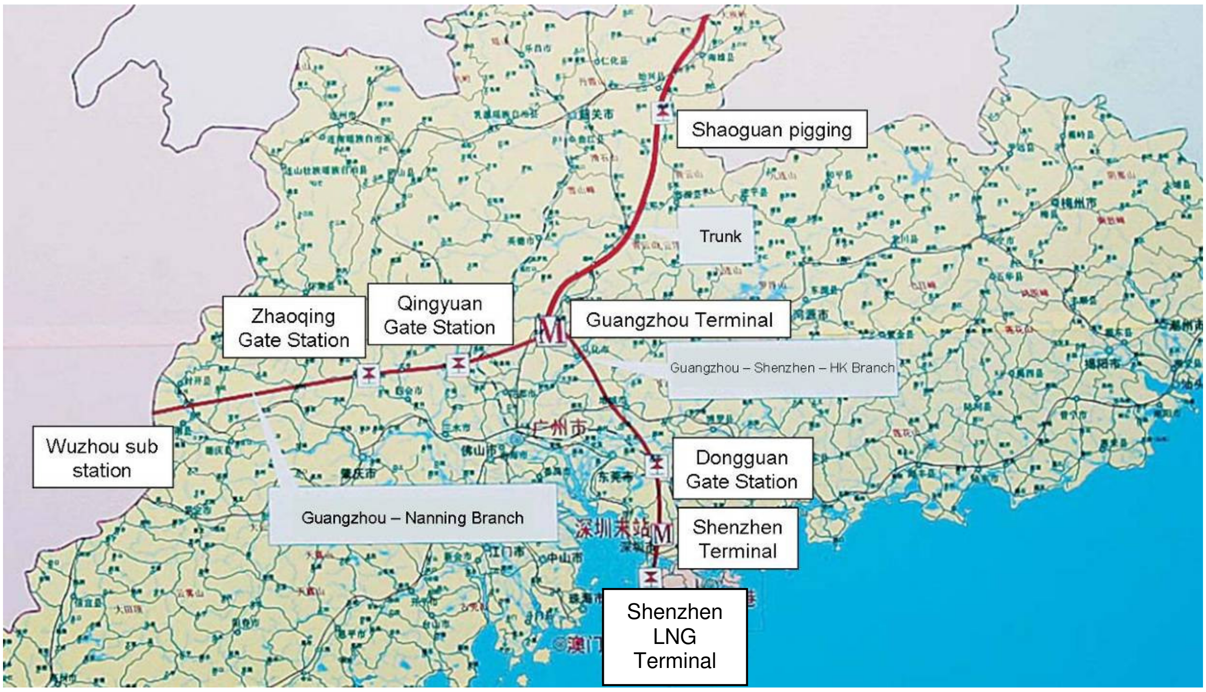

Figure 2 Second West to East Pipeline Route in Guangdong Province

3. DACHAN – BPPS SUBSEA PIPELINE DESIGN

3.1 Route Selection

It is critical for a safety management process to be integrated and maintained throughout the project life. This requires design aspects and operating procedures, by both PetroChina and CLP Project Teams to be combined in a holistic manner to assure safe operations. The pipeline safety management process requires the application of multiple independent controls to protect the pipeline from each identified risk throughout the life cycle of the project.

Route selection is one of the primary controls for avoiding risks to the pipeline and consequences to the public and environment.. In the case of the Dachan – BPPS pipeline, several routes were reviewed before finalizing the selected route (Figure 3).

As part of the route selection exercise, physical and risk constraints of the potential pipeline corridors were reviewed to determine the most appropriate pipeline route. The physical constraints that were considered during the route selection process included:

- Existing and proposed anchorage areas;
- Designated area of marine dredging and mud disposal area;
- Marine sand exploitation area;
- Submarine utilities (e.g. pipeline and cable);
- Heavily trafficked marine vessel fairways; and

- Areas of current, future or proposed reclamation.

In addition, general risk constraints were also identified along the route corridors to reduce the potential risk to the public during the operation of the pipeline. The potential risk constraints that were considered during the route selection process include:

- the general avoidance of populated areas;

- the avoidance, where practical, of areas that were considered to have a high degree of risk associated with their activities (e.g. anchorage areas, major fairways); and

- the selection of the most direct route between the two sites (i.e. Dachan Island and BPPS), to reduce the length of pipeline required.

A collaborative effort between PetroChina and CLP Project Teams resulted in an optimum design that considered subsea soil strata, anchorage areas for marine vessels and crossings of marine traffic access channels. The selected pipeline route reduced physical constraints while minimized risks as far as practical and the routing was finalized after reviews with relevant authorities in PRC and HKSAR (Figure 3). As some of the fairways cannot be avoided, pipeline protection measures are required. A robust study on protection design was conducted and the details are further reviewed in the following sections.

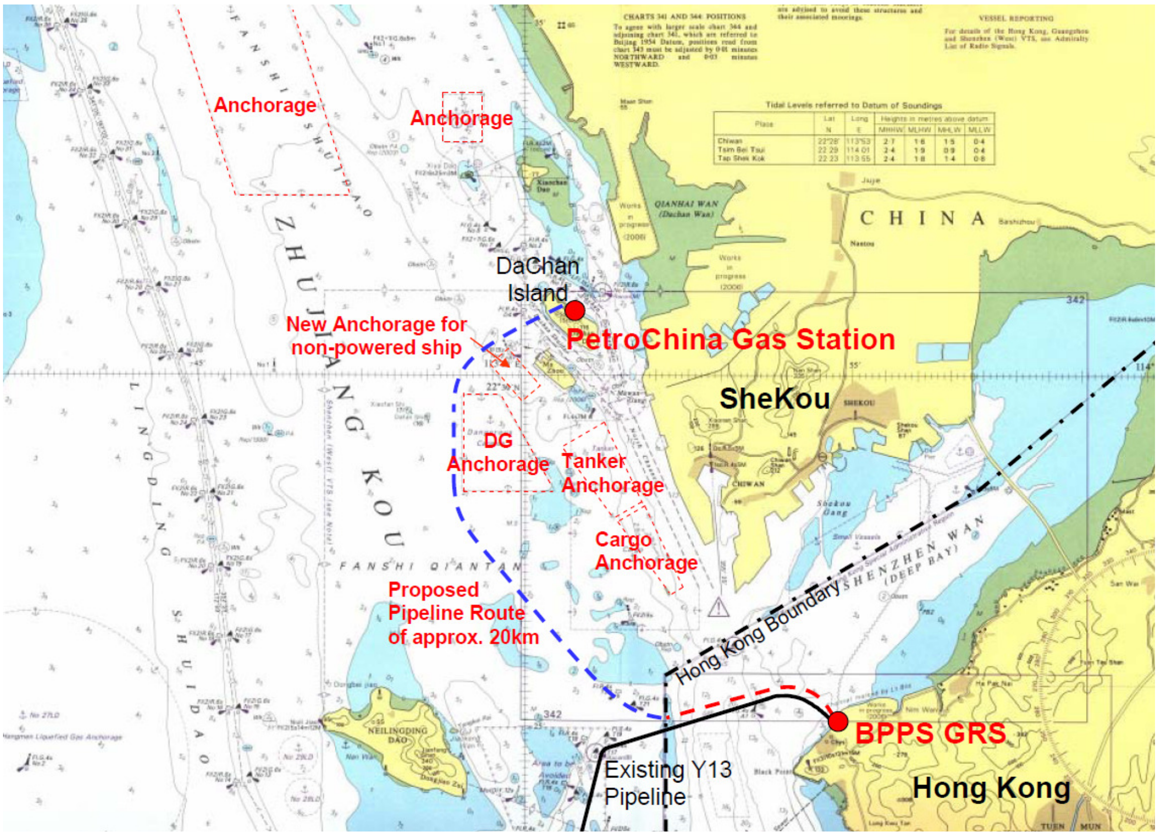

Figure 3 Indicative Route Alignment of Dachan – BPPS Subsea Pipeline

3.2 Pipeline Design

The subsea pipeline was designed with the following characteristics:

Pipeline Design Parameters	
Description	**Data**
Pipe Diameter	32 inch
Pipe Wall Thickness	22.2 mm
Designed for Maximum Operating Pressure	63 barg
External Corrosion Coating	3-Layer Polyethylene
Internal Corrosion Coating	Epoxy
Concrete Coating Thickness	60-80 mm

Several factors were considered in the design of the pipeline including:

- Input from regulatory authorities
- Bathymetry and soils information from route survey
- Interfaces with other sea users such as shipping channels, anchorage areas etc.
- Mechanical protection of pipeline
- Gas supply from PRC sources
- Gas demand requirement conditions for BPPS

International codes and standards have been employed in both HKSAR and PRC and were based on the European, DNV 1981 standards: Rules for Submarine Pipeline Systems. This standard is widely used and recognised in the offshore pipeline industry.

The submarine pipeline route traverses through three busy shipping channels, namely Urmston Road in HK waters and Dachan and Tonggu Channels in Shenzhen waters. To ensure the security of gas supply to BPPS and to reduce the risk of external mechanical damage to the pipeline, rock armour protection against trawling and anchor, in particular anchor drop and drag, will be adopted.

Protection configuration in HK water has been considered based on anchor size of the largest vessel passing through individual pipeline segment determined through a risk-based probability study and supplemented by DNV-RP-F107 – Risk Assessment of Pipeline Protection. The performances of protection designs have been investigated and established from mechanical study, finite element (FE) analysis and a series of anchor drag centrifuge tests conducted by the University of Western Australia Centre for Offshore Foundation Systems (Figure 4). The 3-D non-linear FE analysis with ABAQUS incorporates the complex interactions between the anchor, chain, soil, rock and pipeline. The analysis predicts the anchor penetration depth into the seabed soil, the anchor trajectory within the seabed and armour rock, the minimum clearance between the anchor fluke tip and pipeline and the maximum force exerted on the pipeline. The FE analytical solutions and physical model tests have demonstrated consistent results. With this approach, the rock covers of 1.5 m and 3 m have been developed for protection against 5-tonne and 19-tonne anchors, respectively. To achieve the required level of protection for the Urmston Road crossing section, pre-trenching by grab dredging to bury the pipeline to the required depth (i.e. 3 m below seabed) and backfilling with armour rock would be required (Figure 5). Similar protection design has been adopted for the pipeline sections crossing the fairways in Shenzhen waters.

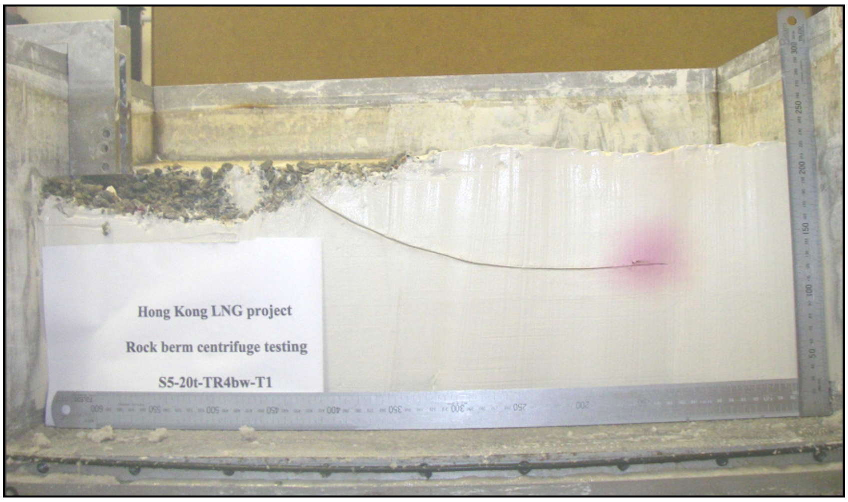

Figure 4 Anchor Drag Centrifuge Test – Anchor Drag Trajectory

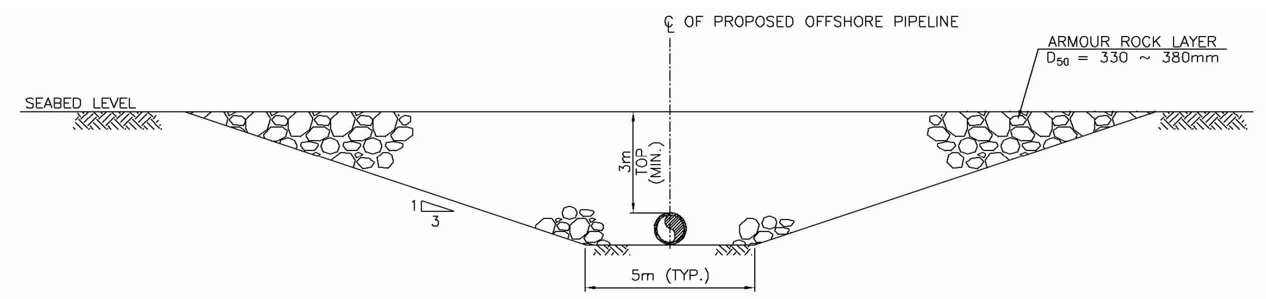

Figure 5 Rock Armour Protection Design for 19-tonne Anchor in Urmston Road

3.3 Pipeline QRA

A comprehensive Quantitative Risk Assessment (QRA) has been conducted as part of the Environmental Impact Assessment (EIA) to assess the potential risks associated with the operation of the submarine gas pipeline in Hong Kong waters [2]. The QRA was undertaken in accordance with the requirements stipulated in the EIA Ordinance – Technical Memorandum

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2 ERM (2010) Black Point Gas Supply Project - Environmental Impact Assessment Report. Submitted to EPD on behalf of CAPCO in February 2010. (Available on the Environmental Protection Department of the HKSAR Government web-site: http://www.epd.gov.hk/eia)

(EIAO-TM). The resulting risk levels were compared against the Hong Kong Risk Guidelines (HKRG) for individual risk [3] and societal risk [4].

The QRA study has considered the loss of containment that may occur due to all possible events, of which corrosion, material defects and third party damage from ship anchor drops/drags were identified as the major risk contributors. Based on a review of the hazards, the marine traffic density and pipeline rock armour protection, the 5 km pipeline within Hong Kong SAR waters was divided into four sections for assessment (Figure 6). Risks have been assessed for each section on a per-km basis to provide a uniform basis for comparison. The findings of the QRA are presented below.

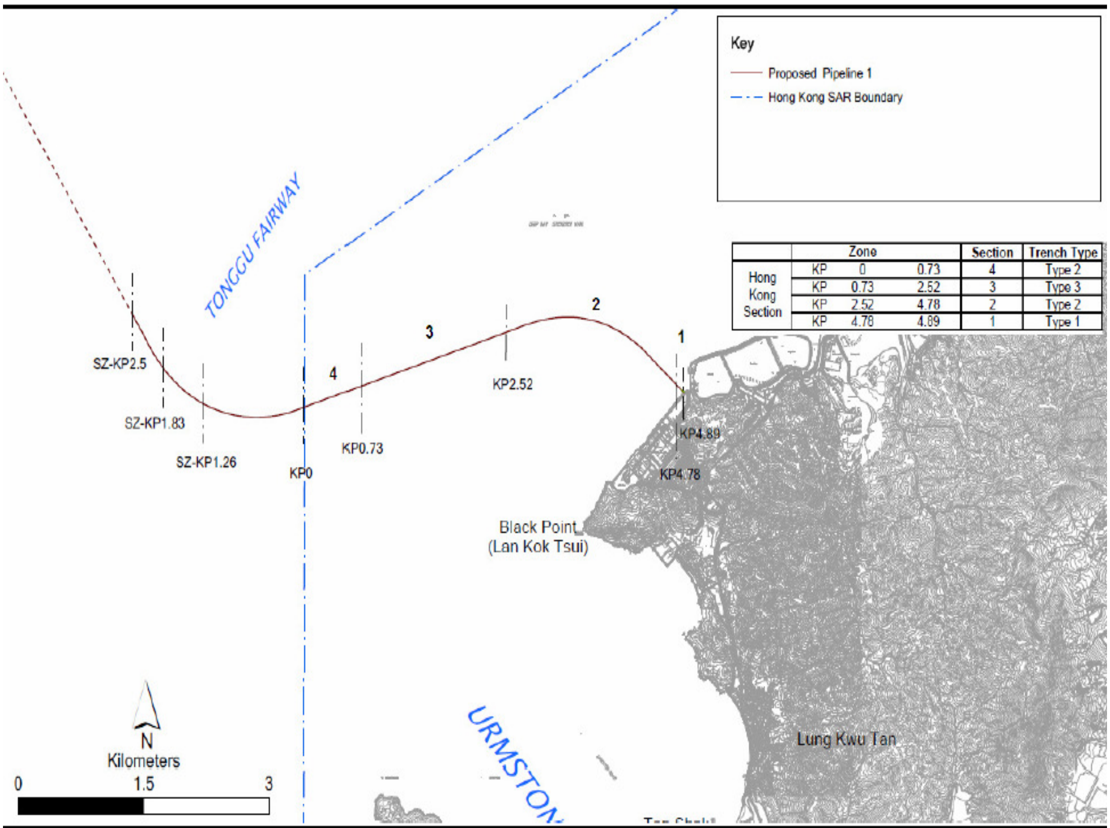

Figure 6 Pipeline Sections for QRA

Individual Risk Results

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3 Individual risk is the predicted increase in the chance of fatality per year to a hypothetical individual who remains 100% of the time at a given stationary point. The individual risk guidelines require that the maximum level of off-site individual risk associated with a hazardous installation should not exceed 1 in 100,000 per year i.e. 1×10^{-5} per year.

4 Societal risk expresses the risks to the whole population. It is expressed in terms of lines plotting the frequency (F) of N or more deaths in the population from incidents at the installation. Two FN risk lines are used in the HKRG to demark "acceptable" or "unacceptable" societal risks. The intermediate region indicates the acceptability of societal risk is borderline and should be reduced to a level which is "as low as reasonably practicable" (ALARP).

The individual risk (IR) is given in Table 1. The highest risks come from Urmston Road where the marine traffic is the highest. The individual risk for all sections, however, is less than 1×10^{-5} per year which is well below the EIAO-TM criterion.

Table 1 Individual Risk Results (per year)

Section		2011 1 pipeline
4	Boundary Section	$9.2\text{x}10^{-8}$
3	Urmston Road	$2.1\text{x}10^{-7}$
2	Black Point West	$6.6\text{x}10^{-8}$
1	Black Point Approach	$9.9\text{x}10^{-9}$

Societal Risk Results

The highest societal risks are associated with Urmston Road (Table 2). The total Potential Loss of Life (PLL), or equivalent annual fatality, for the whole length of pipeline is $2.0\text{x}10^{-5}$ per year.

Table 2Potential Loss of Life Results (per km-year)

Section		2011 1 pipeline
4	Boundary Section	$5.4\text{x}10^{-6}$
3	Urmston Road	$5.8\text{x}10^{-6}$
2	Black Point West	$2.5\text{x}10^{-6}$
1	Black Point Approach	$5.0\text{x}10^{-8}$
	Total	$2.0\text{x}10^{-5}$

The environmental studies concluded that for all pipeline sections in Hong Kong water, the risks (with the requisite protection design) are acceptable per HK EIAO and no further mitigation measures are warranted for the pipeline [5].

The environmental processes for the PRC side are similar in nature to that in Hong Kong and are in a final approval process.

3.4 Safe Operation

5 Details of the QRA study are provided in the Black Point Gas Supply Project EIA Report (available on the Environmental Protection Department of the HKSAR Government web-site: http://www.epd.gov.hk/eia).

Safety systems are designed to ensure safe operation of the gas pipeline system and associated GRS facilities. For example, safety overpressure systems will be situated in Dachan and BPPS. Overpressure protection for BPPS will be provided in the new GRS which shall include a High Integrity Pressure Protection Systems (HIPPS). In the event of high pressures, detected by transmitters installed downstream of the pressure regulators, the isolation valves upstream of the pressure transmitters shall be closed to isolate BPPS from the pressure source.

In case of emergency, the new GRS is isolated using ESD valves installed at both ends of the GRS. Provisions would also be provided on the GRS facilities to automatically blowdown the facility in case of emergencies. Provision is made for depressurisation of the offshore pipeline by manual blowdown through the vent stack at both the BPPS GRS and Dachan Launching Station.

4. DACHAN – BPPS SUBSEA PIPELINE CONSTRUCTION SAFETY

Construction safety is paramount to both CAPCO and PetroChina. To ensure safe construction, safety issues along the pipeline route are being reviewed for alignment on developing appropriate solutions.

To ensure safety during installation, a geophysical survey will be further conducted to confirm the Y13-1 pipeline location before construction. It is known, the proposed pipeline alignment is approximately 100 m from the centreline of the Y13-1 pipeline; necessary monitoring systems and mitigation methods are being planned to assure safe installation. Environmental constraints such as strong currents across Urmston Road, typhoon season and low visibility during foggy periods present additional challenges to pipeline construction and will be addressed during construction planning stages.

Joint constructability workshops are being conducted to assure safety at critical construction locations and execution methods in the pipeline route will be addressed: shore approaches, tie-in points, dredging operations for the pipe trench, sub-marine pipeline installation and the marine channel crossings. Risks for these activities and at these critical locations after appropriate review will incorporate appropriate mitigations into the construction plan.

4.1 Dredging/Jetting Operations

To assure the pipeline is installed to the correct depth, dredging and jetting methods will be adopted. It has been decided to execute the sections in Hong Kong with grab dredge and jetting. The PRC sections may consider using a trailing suction hopper dredge where appropriate.

To ensure safe operations and minimal impact to marine traffic, marine traffic management plan is being developed with Standard Operating Procedures as per local authorities requirements. For example, a working area of 200 m x 200 m is proposed for grab dredger at the Urmston Road section (Figure 7).

Navigation Space West (m)	Proposed Navigation Space During Dredging Operation	Navigation Space East (m)	Navigation Management
0		700	2-way traffic navigation east of Dredger
100		600	2-way traffic navigation east of Dredger
200		500	1- way navigation East of Dredger at either from north or south bound
300		400	1- way navigation and traffic separation recommended
400		300	1- way navigation and traffic separation recommended
500		200	1- way navigation West of Dredger at either from north or south bound
600		100	2-way traffic navigation east of Dredger
700		0	2-way traffic navigation east of Dredger

Figure 7 Dredging Plan and Safety Mitigations

In Hong Kong and in the PRC, access channel dredge methods will incorporate planning and reviews with respective local marine authorities to assure safe passage for marine transit (see section below on MTIA – Hong Kong). Additional equipment such as marine guard boats will be established where appropriate along the construction spreads to assure agreed distances between marine transit vessels are maintained.

4.2 Shore Approaches

Shore approaches are critical in planning efforts to assure over-stressing of the pipeline does not occur during installation. Stress checks are carried out to determine the pipeline burial transitions and vertical radius at the shore approaches. Dachan Island shore approach will be trenched with long-arm excavator based onshore and the remaining sections will be trenched with offshore grab dredger. A linear pull winch will be set up at the landfall. Line pipes will be welded on the pipelaying barge and pulled to the shore. To reduce the weight of the pipeline, buoyancy tanks may be attached. An illustration of a shore pull operation is shown in Figure 8.

At the BPPS shore approach, concrete trough blocks across an existing seawall are proposed. An anchor for the sheave block will be set up at the landfall point at the end of the cofferdam for shore pull operation. The barge pull winch cable will be released from the pipelaying barge, round the sheave block onshore and back to the barge to be connected to the pull head at the pipeline end. Subsequently, the pipe strings will be released from the barge in a controlled manner while the cable is pulled into the barge. Upon completion of the barge pull operation, a prefabricated riser shall be installed followed by a midline tie-in.

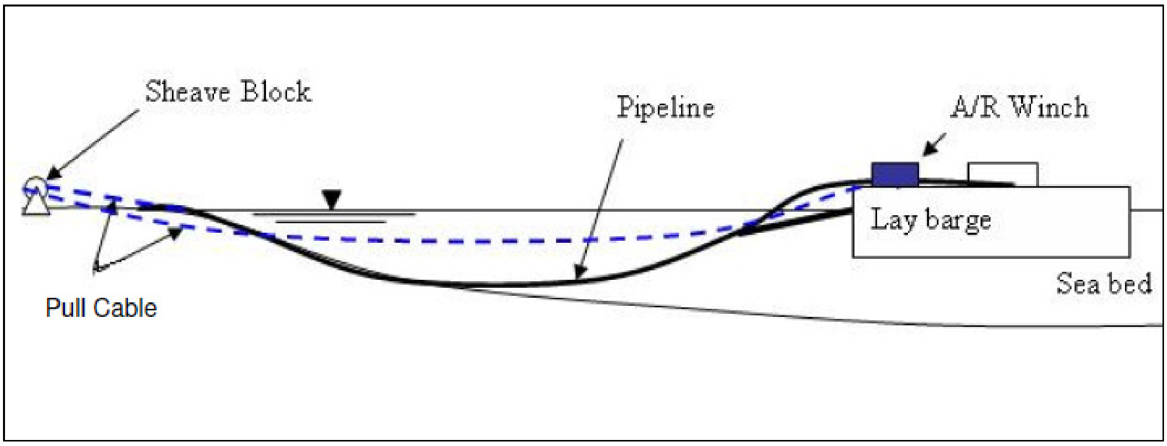

Figure 8 Illustration of Shore Pull Operation

4.3 Sub-sea Pipeline Installation

A primary safety issue is the safe installation in marine access channels. In Hong Kong, Urmston Road is one of the busiest travelled channels in Asia with over 250 instances per day. Considering the construction may affect the marine traffic in HK waters, a Marine Traffic Impact Assessment (MTIA) in Hong Kong water is being conducted to identify all potential impacts to the existing and future marine traffic and facilities during the construction and operation stages of the subsea pipeline and develop mitigation measures to minimise the potential risks and impacts identified. The Hong Kong water MTIA will have certain requirements with an emphasis on safety distances during construction.

4.4 Pipeline Tie-In

The pipelaying operation from Dachan Island is planned to suspend for tying in with the pipeline laying from BPPS at Kilometre Post (KP) 10. The barge will then be repositioned at BPPS shore approach for shore pull and laid down at KP 10. Davit lines will be released and connected to lifting points of both pipeline ends by divers. The two pipelines will then be lifted above water by reeling in the davit lines. After welding the tie-in joint, the pipeline will be lowered to the seabed (Figure 9).

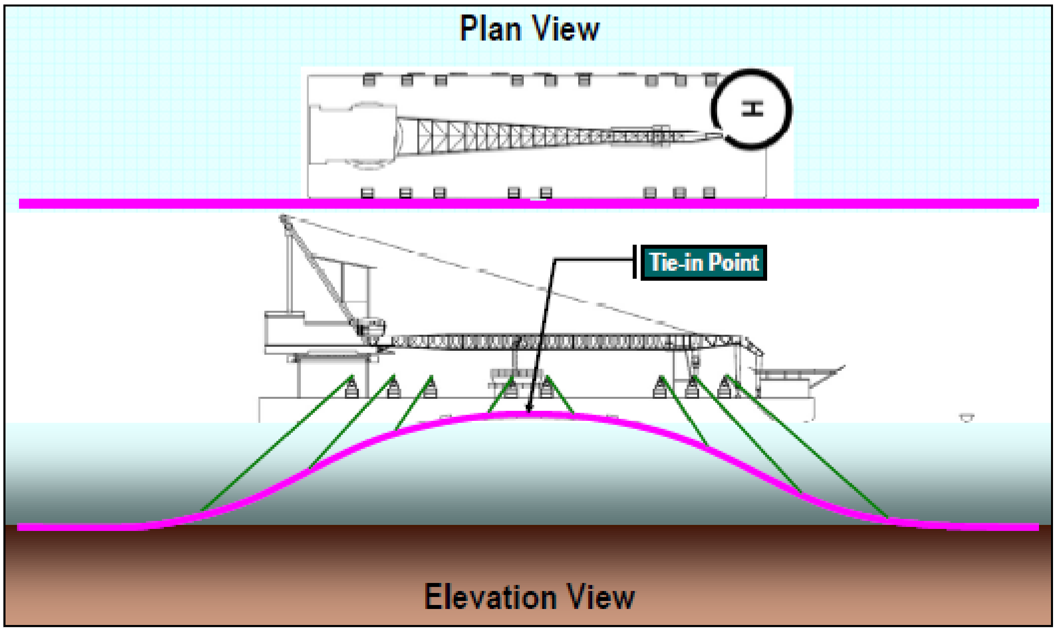

Figure 9 Typical Above Water Tie-In Operation

4.5 Launching/End Stations & GRS

Interface management upstream (Dachan Island) and downstream (BPPS) of the pipeline is an essential component during construction. The HK Launching Station on reclaimed land at Dachan and shore approach are green field developments in association with Shenzhen Gas and PetroChina. The downstream end station is co-located with the existing Yacheng Operating Company (YOC) Gas Receiving Station (GRS) at BPPS. With tight land space at the new GRS and an existing seawall, the construction window needs to be aligned with the end station schedule, in parallel with construction of other GRS facilities. Coordination and alignment workshops with an emphasis on safety, between PetroChina and CLP Project Teams are planned in the near future to assure installation is effective.

5. OPERATION SAFETY

5.1 Operation Management

An integrated and continuous operational safety management is a key to ensure the safe operation of the pipeline, which will be developed during the construction phase of the pipeline. The subsea pipeline inspection will include both internal inspection and external inspections.

The external inspection shall include the following:

- Assure the pipeline buried depth meets design requirement, standard specification and other special requirement.
- Inspection for local scour phenomenon and sand wave movement
- Inspect for excessive pipeline movement because of expansion or other causes.
- Inspect integrity of armour protection layer,

- Inspect the operation of the external anti-corrosion system including cathodic protection and coating.

- Inspect internal and external corrosion and erosion status.

Use of an intelligent pigging equipment to inspect the internal condition of the pipeline. By inspecting the pipe wall thickness, the integrity of the pipeline can be confirmed.

- Check the internal diameter of the pipeline

- Check the XYZ coordinate of the pipeline

- Check the pipeline wall thickness loss

5.2 Pipeline Emergency Procedure

CLP and PetroChina Project Teams will define and implement procedures to assure proper mitigations are in place for the safety of surrounding population/ plant personnel in the event of a pipeline emergency incident. Building on the existing emergency management system's of CAPCO and PetroChina, a specific emergency management system for the pipeline will be established. Key stakeholders such as police, fire departments and regulatory agencies such as Electrical and Mechanical Services Department (EMSD) in Hong Kong will be consulted and involved in the emergency response procedures.

6. CONCLUSION

Safety Management is a full life-cycle process. Risk management of the pipeline should be carried out at each stage of the pipeline project. Effective technical and management measures should be taken to ensure the safety of the pipeline are controlled within an acceptable range.

The conditions of the pipeline: external, internal and operational conditions are expected to change over time. Risk management is therefore a dynamic process requiring the levels of risk be monitored real time.

Close management and interfaces between stakeholders/parties on the HKSAR and PRC are essential for the successful execution of the project. The contracting strategy for the Engineering, Procurement and Construction (EPC) of the project is being developed to secure effective management and rapid communication between the parties involved for the HKSAR and Shenzhen segments. Under the Joint Venture partnership, PetroChina and CAPCO Project Teams are ensuring an effective safety management process is integrated and implemented through the pipeline's life-cycle. Our goal is to demonstrate to a wider audience that Safety truly does not have a border.